PA 222121

59501

See inside

FINAL REPORT

SAMPLE PROVISION FOR BIOLOGICAL AEROSOL DETECTION

broken lines

"DTIC USERS ONLY"

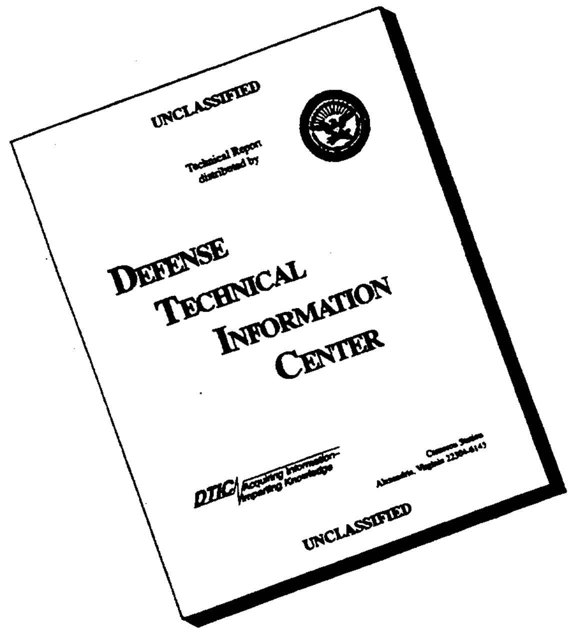
19960501 119

APPLIED SCIENCE DIVISION
LITTON SYSTEMS, INC.
LITTON INDUSTRIES

DTIC QUALITY INSPECTED 1

RECD MAY 23 1966
Litton Industries

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

FINAL REPORT

SAMPLE PROVISION FOR BIOLOGICAL AEROSOL DETECTION

broken lines

"DTIC USERS ONLY"

Customer Order Number
SU-637537-64

Prepared for:

Melpar, Inc. no underline
Falls Church, Virginia

Submitted by: [signature]

LaVerne W. Rees, Manager
Aerosol Physics

Prepared by:

Leonard Graf

Approved by: [signature]

A. A. Anderson, Director
Applied Research

Report No.: 2822
Project No.: 59501
Date: 15 July 1965

p. 49

APPLIED SCIENCE DIVISION
Litton Systems, Inc.
2295 Walnut Street
St. Paul, Minnesota 55113

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FINAL REPORT

SAMPLE PROVISION FOR BIOLOGICAL AEROSOL DETECTION

I. SCOPE OF WORK

A. General Purpose

This report describes the work performed necessary to develop, design, fabricate, test and evaluate a miniaturized version of the Large Volume Air Sampler (developed for the U.S. Army Biological Laboratories under Prime Contract DA 18-064-CML-2849(A)). This sampler is a compact, self-contained unit, similar in operational principle to the present Large Volume Air Sampler. Reductions were made in size (11-3/4" x 11-3/4" x 18" high), weight (41 lbs) and power requirements (150 watts) to correspond to the reduced sampling rate. The sampler is capable of continuously collecting, on a per minute basis, the particulate matter from 1000 liters of air and concentrating it into about one milliliter of glycerin.

The collector is fundamentally an electrostatic precipitator of unusual geometric configuration. Airborne particles, charged as they pass through a corona discharge at the sampler inlet, are precipitated onto a thin, moving, liquid film which completely wets or coats the collector surface, a rotating disk. Centrifugal force, set up by the disk rotation, causes the liquid to flow from the disk center outward into a channel at the periphery of the disk. From this channel the liquid is picked up with a static probe and continuously delivered to a point outside the sampler for analysis.

The Fractionator or Liquid Processing Unit developed by the Applied Science Division (also under the above contract) for use with the present Large Volume Air Sampler was also modified to make it compatible and mateable with the miniature sampler. Significant modifications were the design of a processing cup to accept a liquid flow rate of 1 ml/min, and modification of the liquid collector device to minimize the process time of the Fractionator.

The Fractionator is a device which separates nonmicrobiological from microbiological particulate matter suspended in liquids of the appropriate density (glycerin). Separation of particulate matter is based on the differential settling velocity of these particles when suspended in a liquid. The differential settling velocity is greatly accelerated in the Fractionator by spreading the liquid out in a thin film and subjecting it to a high centrifugal force.

Both units, i. e., the miniaturized version of the Large Volume Air Sampler and the modified Fractionator have performance characteristics comparable to the present Large Volume Air Sampler and Fractionator, except insofar as the absolute values are modified by the reduction in size. The units have been designed for a routine continuous operation. One milliliter of liquid per minute containing the concentrated atmospheric sample is delivered to a continuous flow system. The units have also been designed in such a manner that use of the Fractionator with the sampler shall be at the user's option.

B. Limits of Work

During the development phase several operational factors were investigated to establish results upon which the design would be based. For the sampler, the individual working components were performance tested for optimum results and reliability. Tests were conducted on various wetting agents, collector disk speed and liquid pickup devices

to determine parameters for satisfactory transport and delivery of the collected particulate matter. High voltage plate dimensions and voltage gradient were investigated to optimize size, power requirements and collection efficiency. An integrated laboratory model of the sampler was tested to determine if the overall performance was comparable to the present Large Volume Air Sampler. For the Fractionator a processing cup was designed to process liquid at 1 ml/min, yet have a performance comparable to the present Fractionator. The liquid collector device was modified to maintain a process time on the order of one minute.

After the prototype units were fabricated and assembled, complete tests were made to establish their performance characteristics and minor modifications were made to improve their performance. A final test was made of each unit.

C. Applications of Work

Testing the individual sampler components for performance resulted in determining to what extent weight, size and power requirements could be minimized and yet maintain the desired performance characteristics. Incorporating the individual components into an integrated sampler was necessary to determine if a complete system would perform satisfactorily under actual operating conditions. Satisfactory completion of these tests permitted the design and fabrication of the final model. The Fractionator cup was modified to handle 1 ml of particle laden liquid per minute. Satisfactory modifications of this cup means continuous operation of the system and removal of the undesirable background particulate matter from the particle laden liquid.

Complete tests of the prototype models were made to establish the performance of the units and minor modifications were made, if necessary, to insure satisfactory performance. Final tests were made to determine the exact operating characteristics.

II. OBJECTIVES FOR THE CONTRACT PERIOD (December 1, 1964 through June 30, 1965)

The overall objective of this project was to design, fabricate, and test a miniaturized version of the Large Volume Air Sampler and a mateable Fractionator. A review was made of experimental work on the Large Volume Air Sampler to eliminate duplication and to assist in determining significant design parameters for the miniature sampler. Tests of the individual components of the sampler were made to determine their optimum size and configuration for a given performance. A processing cup was designed, fabricated and tested to determine feasibility of fractionating particle laden liquid at a flow rate of 1 ml/min. Prototype units of the sampler and Fractionator were tested and evaluated to determine their performance characteristics. The final units were shipped to the sponsor on schedule.

III. RESULTS AND DISCUSSION

A. Major Results

1. Sampler-Laboratory Model

After a review of data and experimental work on the Large Volume Air Sampler, a laboratory model of the air sampler was fabricated (see Figure 1). Provisions were made for adjustment of the variables, such as high voltage plate and collector plate dimensions, plate to plate spacing, collector plate speed, air flow rate, and liquid flow rate.

Tests to determine the conditions at which a flow rate of 1 ml/min would adequately wet a rotating disk were made varying liquid flow rate, wetting agent, and disk speed. Adequate wetting was observed ~~at disk~~ speeds of 1000-1800 rpm using 90% Glycerin + 0.1% Brij 35 as the liquid. Brij 35 is polyoxyethylene (23) laurel ether manufactured by Atlas Chemical Industries.

Figure 2 shows a breadboard model of the disk used to experimentally determine the desirable configuration for the liquid pickup probe. Figure 3 shows a type of pickup probe which performed satisfactorily under laboratory conditions, readily collecting glycerin at the rate of 1 ml/min with an acceptable amount of mixing.

The laboratory model of the miniature sampler was tested for collection efficiency, varying certain parameters to determine optimum configuration. At the design air flow rate of 1000 1/min the efficiency for 0.9 micron (MMD) particles was in the range of 81 to 98%. The pressure drop, and thus the blower power requirements, at all of the configurations was within reasonable limits.

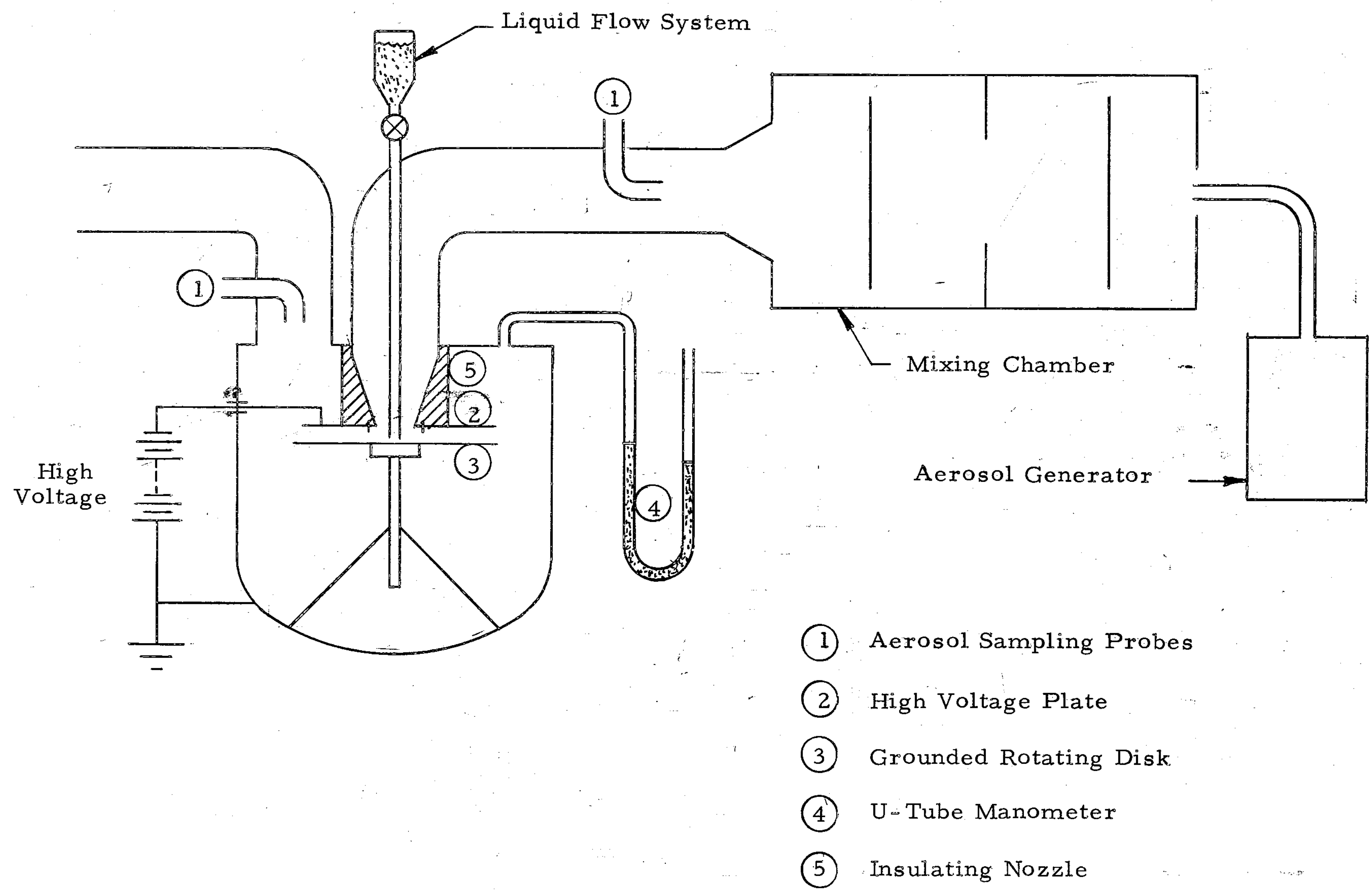


Figure 1. Apparatus for Testing Laboratory Model of Sampler

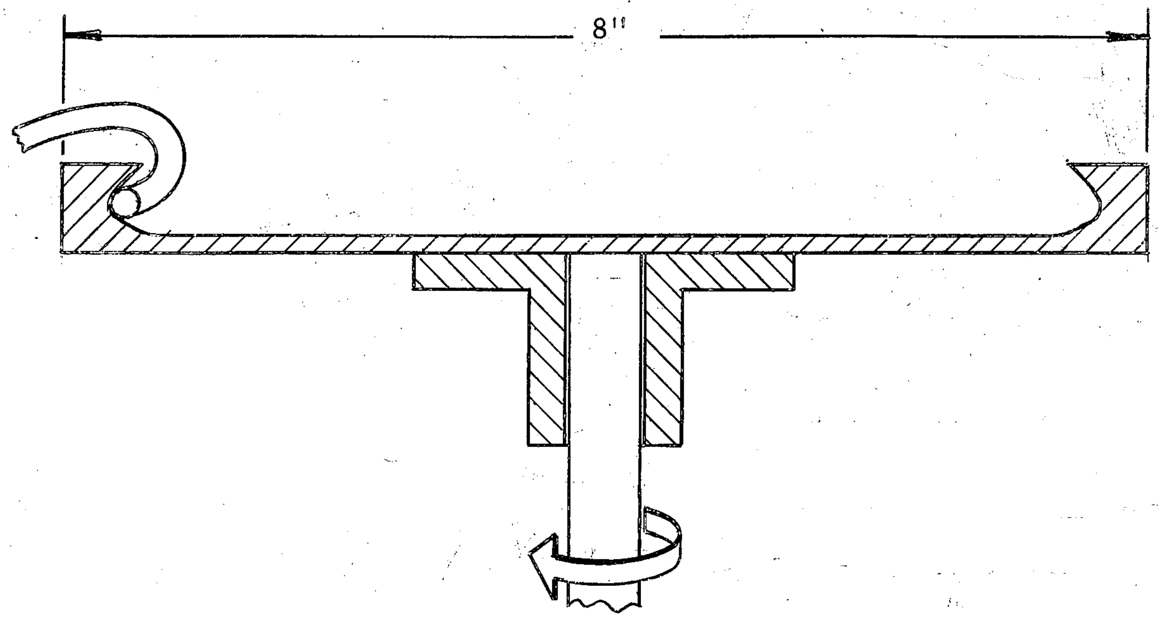


Figure 2. Diagram of Liquid Pickup Apparatus

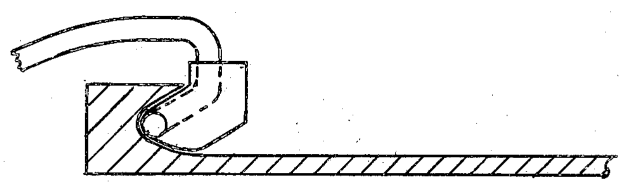


Figure 3. Contour-Fitting Pickup Probe

2. Fractionator - Laboratory Model

A modified cup for the Fractionator was designed, fabricated and tested to establish the separation efficiency. The efficiency for particulate matter more dense than the liquid was comparable to the present Fractionator. However, for particulate matter less dense than the liquid it was necessary to test several modifications of the cup in order to obtain a separation efficiency equivalent to the present Fractionator. The collector cylinder of the present unit was replaced with a concentric rotating cylinder and wiper to collect the liquid after processing by the cup in order to keep the processing time on the order of one minute.

3. Sampler - Prototype Model

Figure 4 shows a schematic of the final model of the sampler. Figures 5, 6, and 7 show various views. The sampler was calibrated for air flow versus pressure drop and at 1000 l/min the pressure drop is 0.52 inches of water. The liquid flow rate was adjusted to 1 ml/min. At these normal operating conditions the unit was tested for collection efficiencies for various size particles. In all cases the collection efficiency was higher than that of the original Large Volume Air Sampler. The collection efficiency of the sampler for Bacillus Globigii was tested and the average value for six tests was 93%. The response time is about the same as the present Large Volume Air Sampler.

4. Fractionator - Prototype Model

Figures 8 and 9 show schematics of the Fractionator and Figures 10 and 11 give views of the unit. Figure 12 shows the sampler and Fractionator when in mated operation. Tests were conducted with the Fractionator operating at 5,000, 10,000, and 20,000 rpm. The

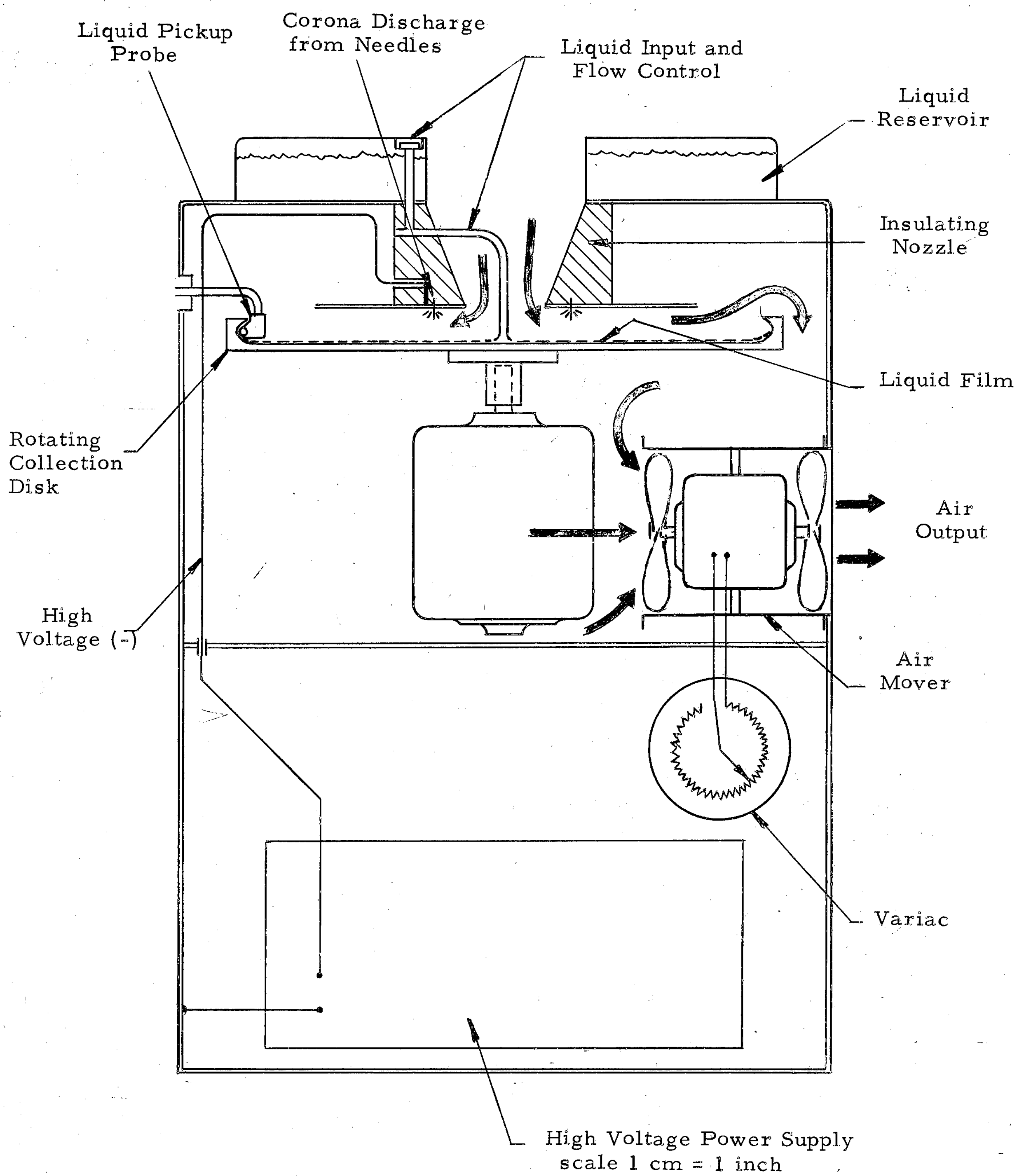


Figure 4. Schematic of Air and Liquid Flow System of Sampler

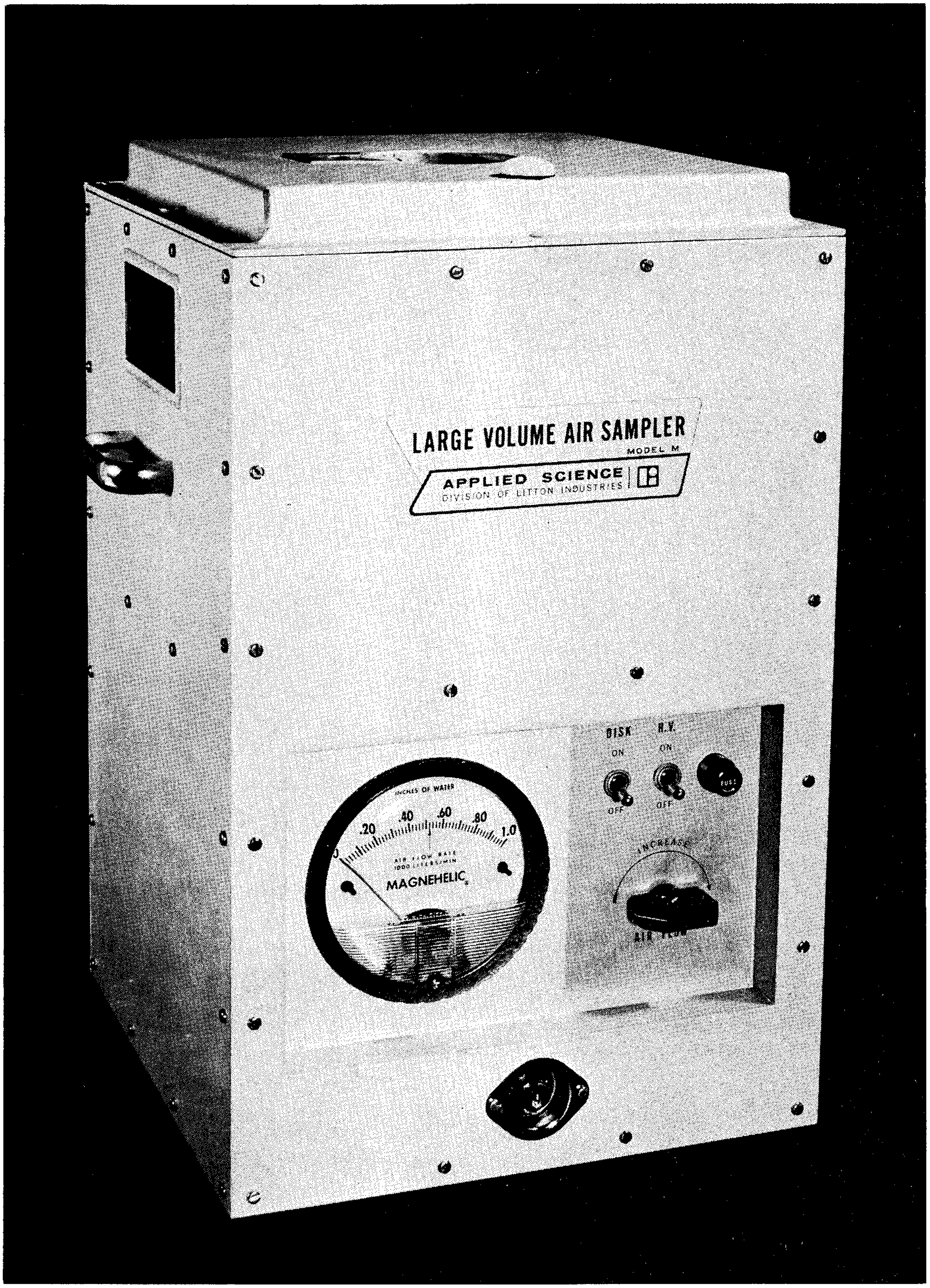


Figure 5. Air Sampler - Front View

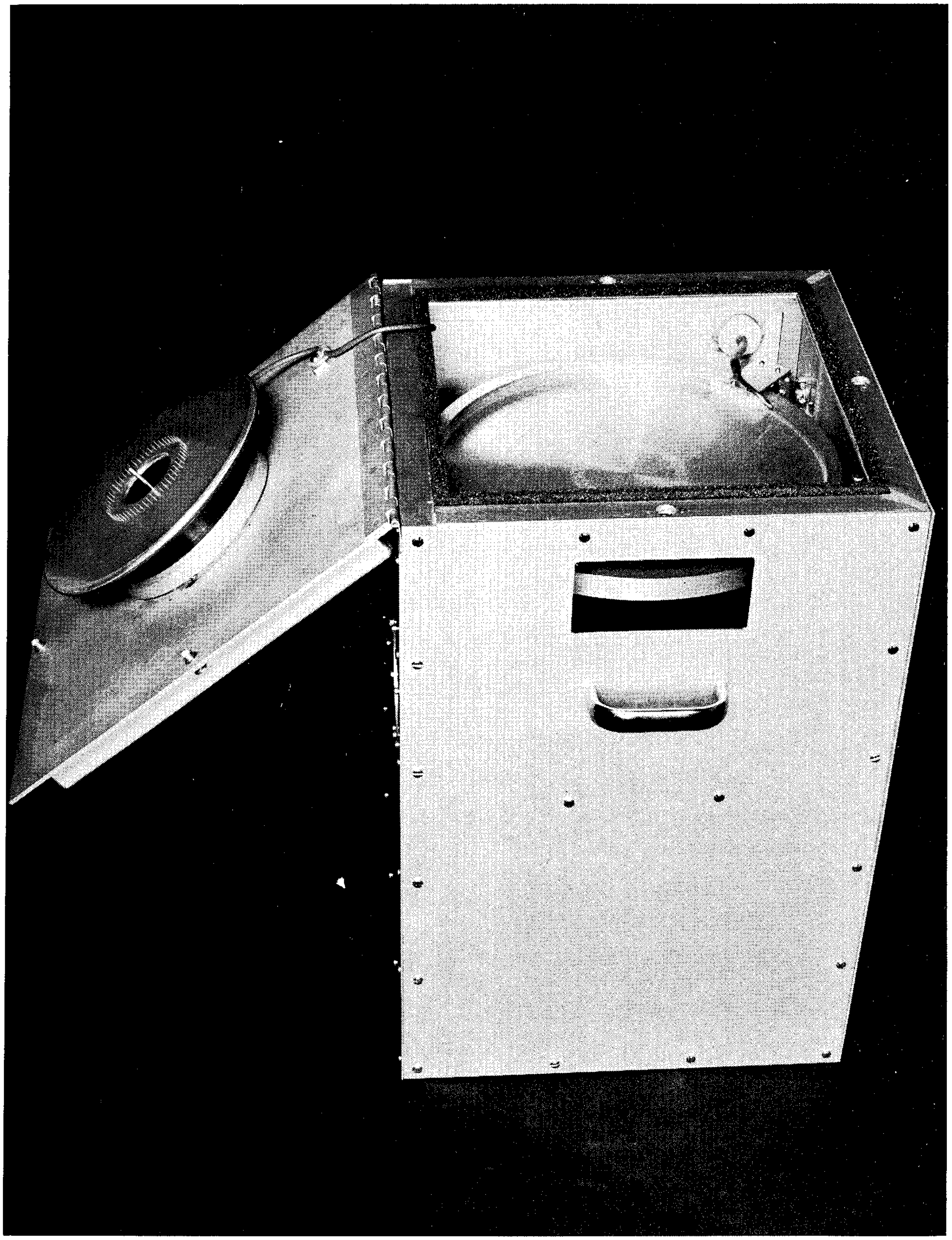


Figure 6. Air Sampler - Side View
(top cover open)

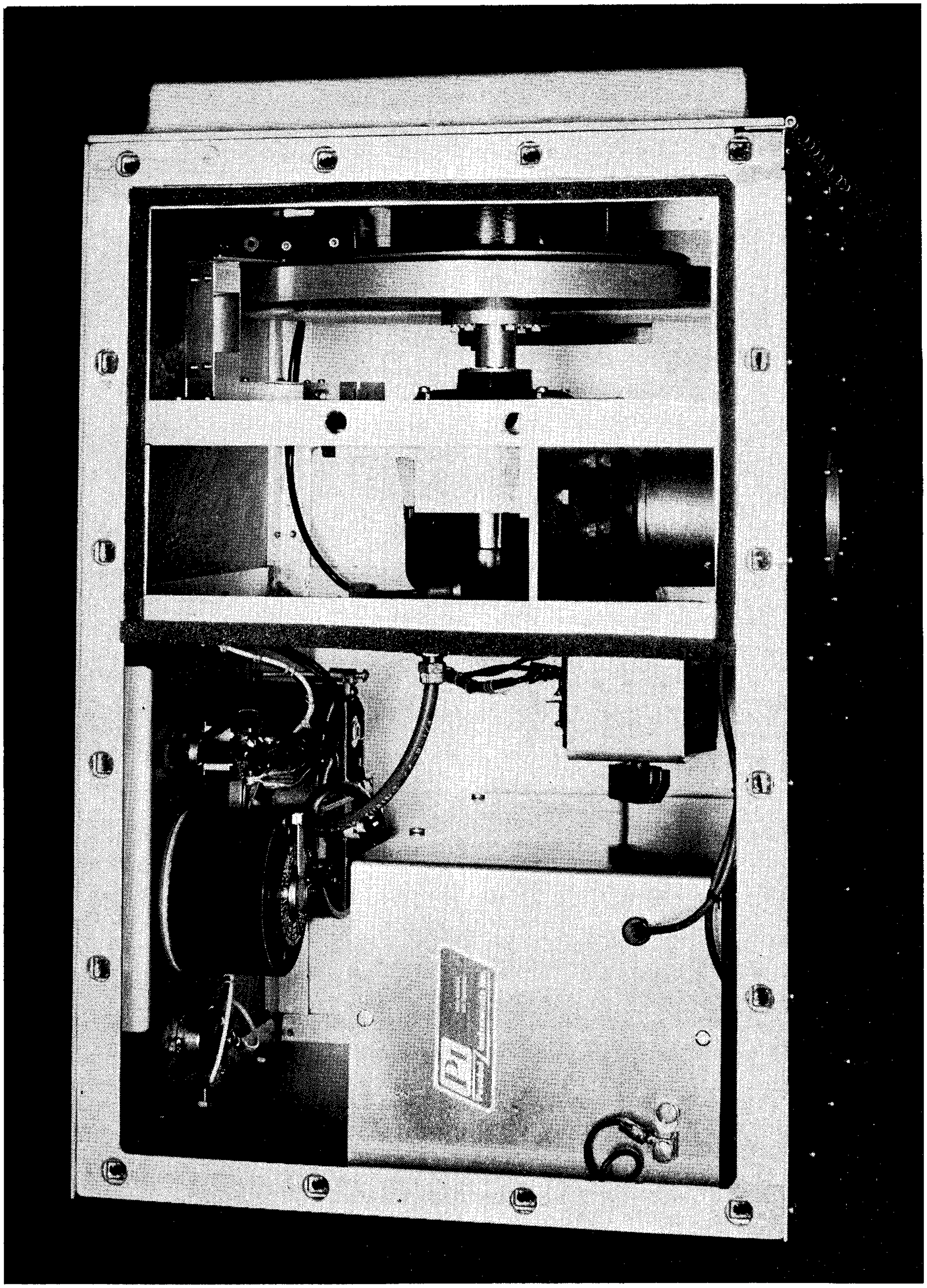


Figure 7. Air Sampler - Side View
(panel removed)

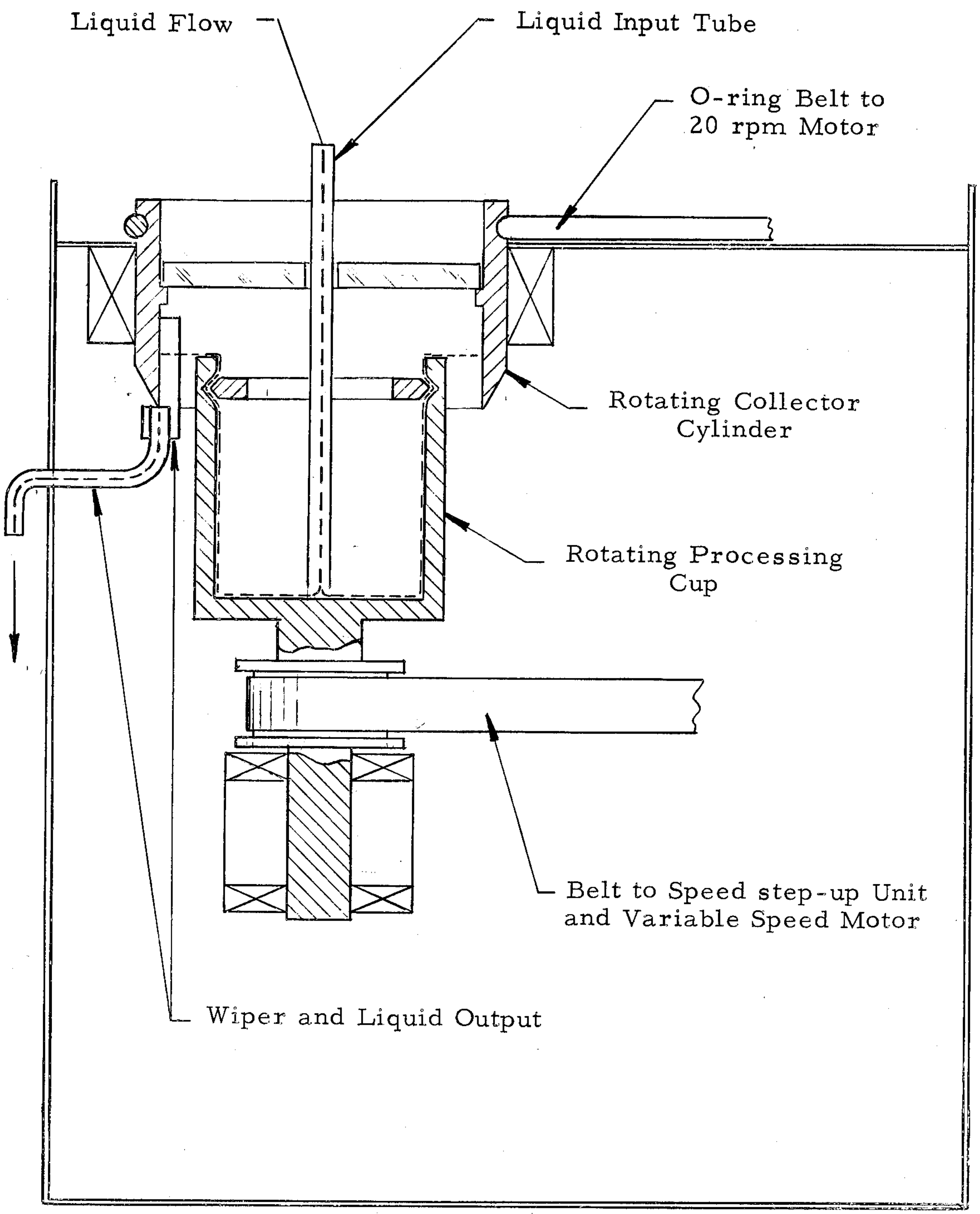


Figure 8. Schematic of Fractionator

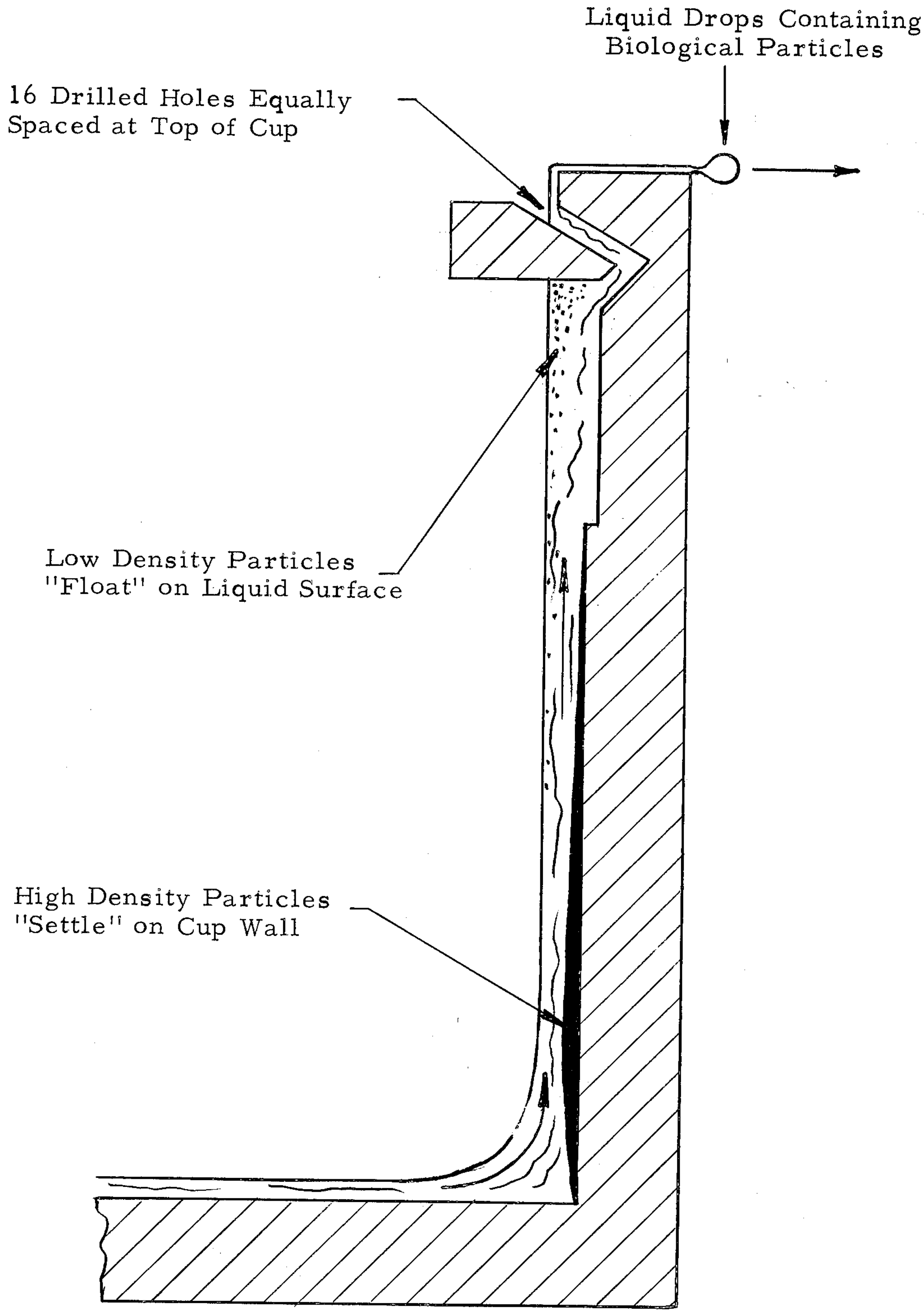


Figure 9. Enlarged Section of Fractionator Cup
Showing Method of Density Separation

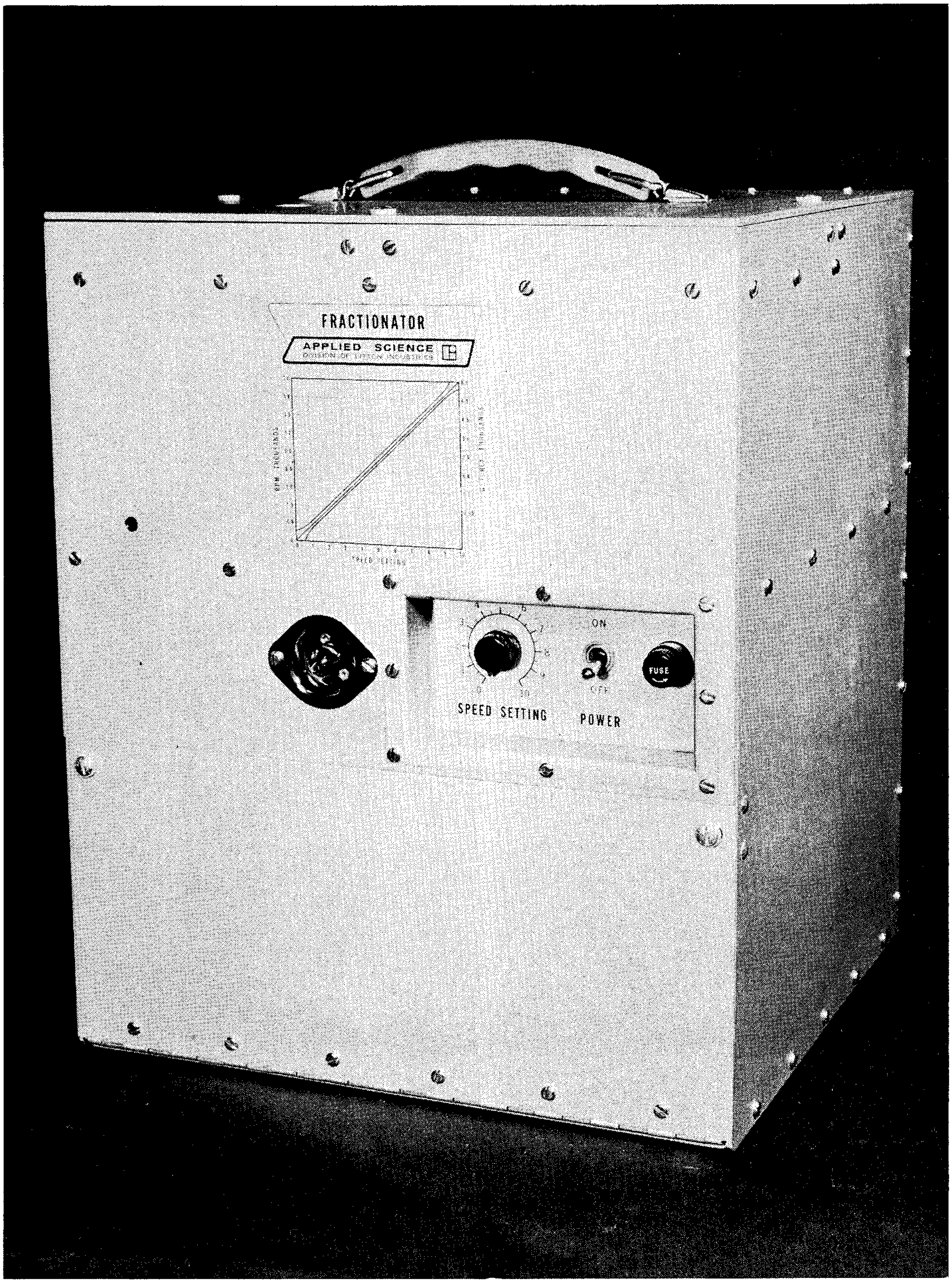


Figure 10. Fractionator - Front View

5577

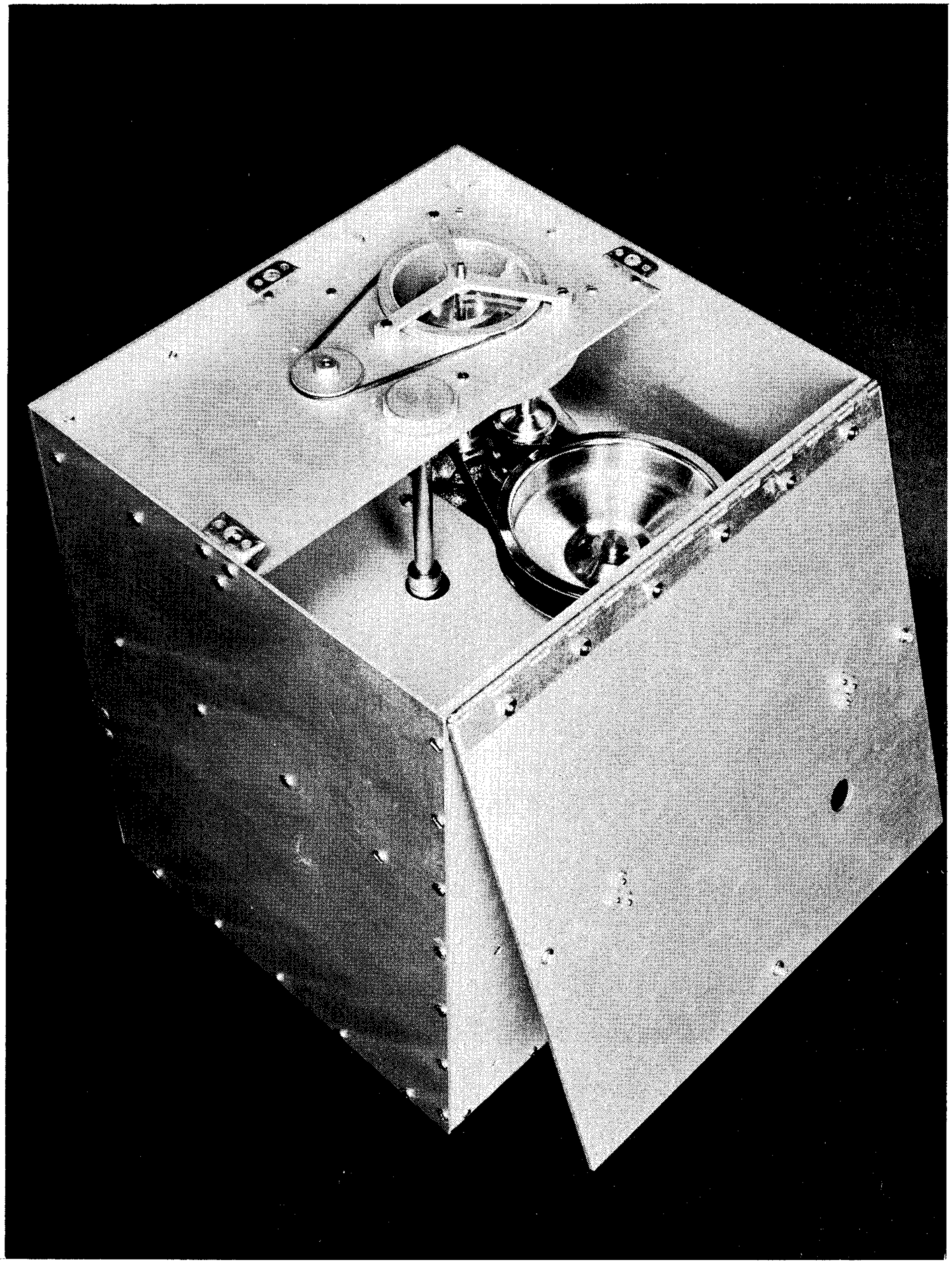


Figure 11. Fractionator - Top View

5579

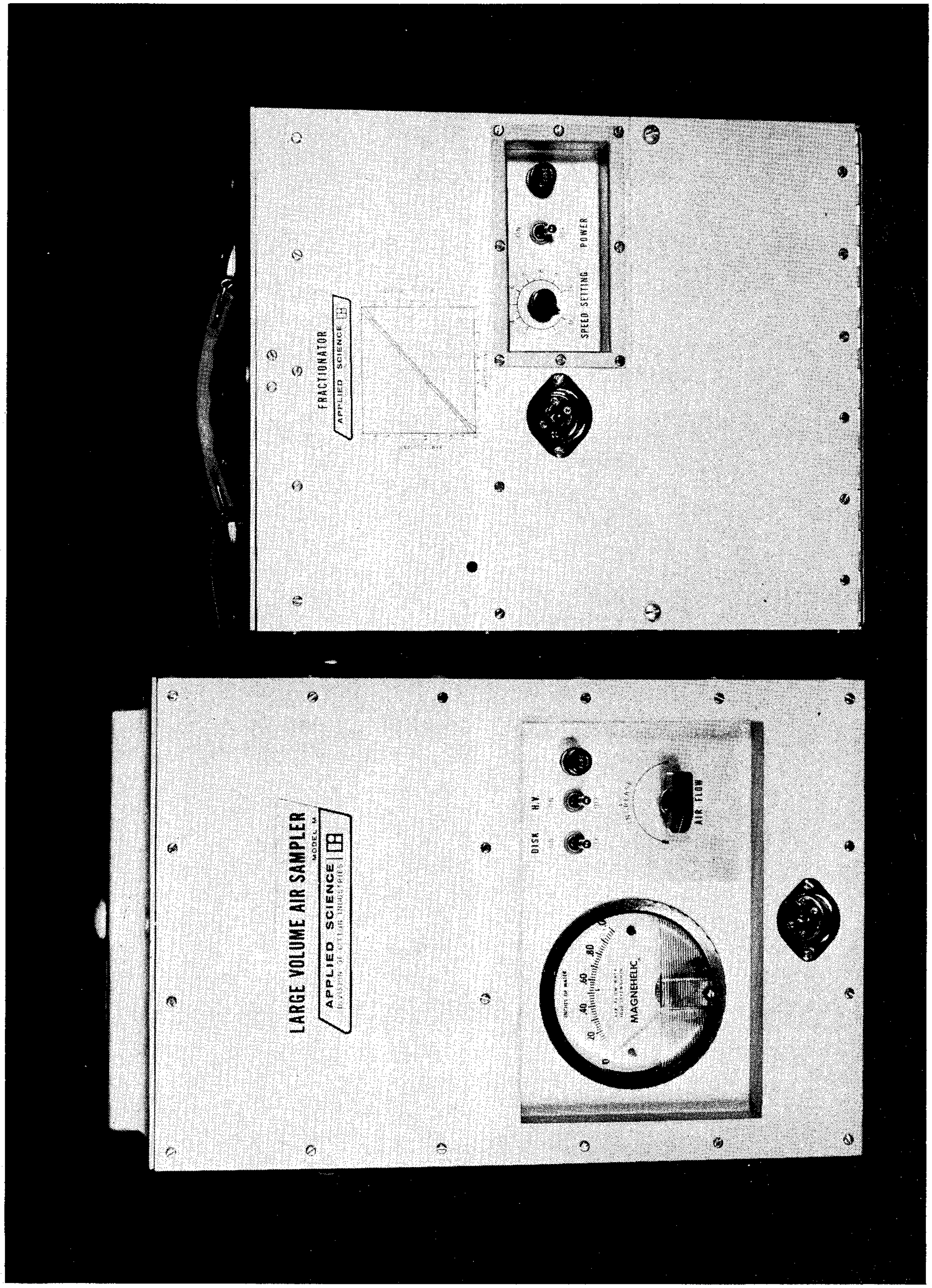


Figure 12. Sampler and Fractionator

efficiency at all conditions was the same as that of the laboratory model. After some modification of the wiper for the collector cylinder, the response time was observed to be on the order of one minute, with very little mixing. For all of these tests the liquid flow rate was 1 ml/min. A calibration curve of cup speed versus speed setting was drawn up and mounted on the front plate of the unit.

B. Discussion

1. Sampler

A review of the data and dimensions of the Large Volume Air Sampler provided the necessary preliminary information to determine the approximate dimensions and configuration of the miniature sampler. By appropriate mathematical analysis it was determined that the orifice diameter should be approximately 1.5 inches and the diameter of the high voltage plate in the neighborhood of 7 to 9 inches. Preliminary analyses indicated that the diameter of the rotating collection disk should be approximately 9 to 12 inches. These analyses also indicated that in order to use a static pickup probe the rotating disk should have a groove or reservoir at the edge for the liquid pickup process.

Collection efficiency tests on the laboratory model of the sampler were made, varying the high voltage plate diameter from 9 inches to 7 inches and varying the plate to plate spacing from 3/4 inch down to 9/16 inch. (The needles were maintained at a constant position; i.e., positioned on a 2.5 inch diameter circle, spaced 1/8 inch apart and protuding 1/8 inch from the high voltage plate.) These tests were conducted to determine the minimum dimensions at which the sampler could operate and still have a collection efficiency comparable to the Large Volume Air Sampler. Reduction in size correspondingly is a reduction in weight and power requirements. From the results of

these tests the following conclusions were drawn with respect to design: high voltage plate diameter - 7 inches, plate to plate spacing - 9/16 inch, high voltage power supply requirements - negative 15,000 vdc at 3 ma.

A gravity fed system with a suitable control device was selected for this sampler to increase reliability and simplicity. To maintain a uniform liquid flow rate from a reservoir in which the liquid level is changing, consider Figure 13. The liquid flow rate is Q is proportional to $P_R + h_1\rho_\ell + h_2\rho_\ell - P_A$ where

P_R = pressure in the reservoir

h_1 = height of liquid level above liquid outlet

h_2 = length of tubing from which liquid flows

P_A = ambient pressure

ρ_ℓ = liquid density

For an open reservoir $P_R = P_A$ and $Q \sim (h_1 + h_2)\rho_\ell$

The flow rate will change with the liquid level. For a completely sealed reservoir, liquid will flow until

$$P_R = P_A - (h_1 + h_2)\rho_\ell$$

Then

$$Q \sim (P_A - h_1\rho_\ell - h_2\rho_\ell) + h_1\rho_\ell + h_2\rho_\ell - P_A = 0$$

For a vented tank as shown in Figure 13, at steady state flow

$$P_R = P_A - h_1\rho_\ell$$

and

$$Q \sim (P_A - h_1\rho_\ell) + h_1\rho_\ell + h_2\rho_\ell - P_A = h_2\rho_\ell$$

Since h_2 is fixed, the liquid flow rate is uniform.

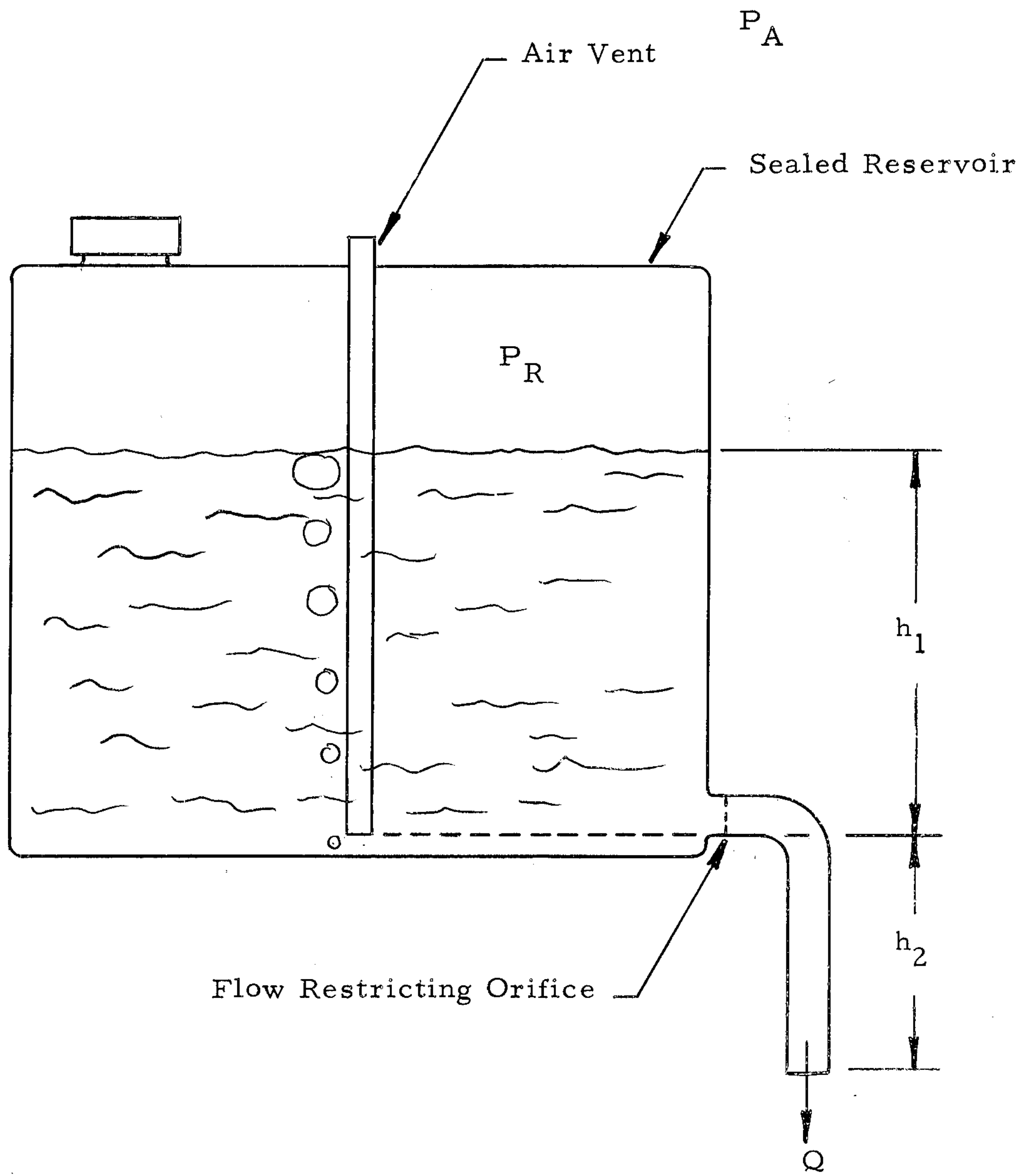


Figure 13. Schematic of Uniform Flow Liquid Reservoir

Tests in the laboratory indicated that a flow control device of this type works satisfactorily. Variables such as viscosity will effect the flow rate.

The rotating speed of the collector disk must be maintained within certain limits to satisfy two conditions: (1) low enough to maintain a continuous film of liquid over the entire surface and to allow pickup of the liquid at the periphery, and (2) high enough for reasonably short liquid traverse time across the surface. A speed between 1000 - 1800 rpm satisfied these conditions.

In order to efficiently and continually remove all particles collected on the collection disk surface, the liquid used for such transportation must completely wet the disk. The liquid recommended for the Large Volume Air Sampler is glycerin plus 0.4% Tween 20 (Polyoxyethylene (20) sorbitan monolaurate - Atlas Chemical Industries), a wetting agent. This solution was tried but at the desired flow rate of 1 ml/min it did not adequately wet the disk. Another wetting agent, Brij 35, was tried and using glycerin plus 0.1% Brij 35, adequate disk wetting was obtained.

The proposed liquid pickup probe employs no moving parts. To reduce the weight and power requirements of this sampler it was envisioned that some components, such as the liquid pump, could be eliminated. Previous work on liquid pickup indicated that under certain conditions liquid could be picked up with a static probe from a reservoir at the edge of a rotating disk without the use of a pump. By pointing a probe "upstream" into the rotating liquid, the velocity head will force the liquid through a tube.

This method of liquid pickup had one major problem to solve - mixing and its effect on response time. Mixing should be kept to a minimum since it is desirable that all particles entering the collector within a certain time increment be in the same increment of liquid leaving the collector.

Probes of various configurations were fabricated by melting solder in the groove at the edge of the disk, thus giving a contour-fitting pickup probe. A piece of copper tubing in the appropriate position was also affixed to the probe with solder. After some additional shaping of the probe a model was built that solved the mixing problem. The greatest disadvantage of this type of a pickup probe is the sensitivity of the probe to alignment and position.

The prototype model of the sampler was fabricated and assembled. (see Figures 4, 5, 6, and 7). Below are listed some of the basic nominal statistics:

Size = 11-3/4" x 11-3/4" x 18" high
Weight = 41 lbs (liquid reservoir empty)
Air inlet = 3" diameter
Orifice = 1-1/2" diameter
Needle circle = 2-1/2" diameter (60 needles)
High voltage plate = 7" diameter
Rotating collection disk = 10" diameter (at point of liquid pickup)
Plate to plate spacing = 9/16"
Liquid reservoir capacity = 1300 ml
Power input = 150 watts (at 115v, 60 cycle)
Pressure differential at 1000 l/min = 0.52 inches water

The top cover assembly of the sampler is hinged and can be opened up by loosening the quarter-turn screws holding it in place. The right side of the unit is held in a similar manner and can be removed for inspection of working parts. On the left side is a viewing port to observe various components when the sampler is in operation. The front cover contains the control panel and differential pressure gage.

Air enters the collector (Figure 4) through a converging nozzle at the sampler top and is drawn through a hole in the center of a 7 inch diameter high voltage plate. Air flow is then directed outward between the high voltage plate and a parallel rotating collection disk separated by 9/16 of an inch from the high voltage plate. As the air starts to flow outward, it passes through a corona discharge from a ring of needle tips set back slightly from the hole in the top plate. This corona discharge is produced by maintaining the top plate and needles at a negative potential of 15, 000 volts dc.

Particles in the air are charged as they pass through the corona. An electrical force then acts on these charged particles as they pass through the high voltage gradient area between the two parallel plates. As the air flows radially outward from the center of the plates, the velocity decreases proportionally as the square of the radius, thus allowing sufficient time for the electrical force to move the charged particles toward the rotating collection disk surface.

Particles are electrically precipitated onto a thin moving film of liquid which coats the lower rotating disk or plate. Centrifugal force, caused by rotating the collection disk, forces the liquid, which is continually being fed onto the plate from a centered tube, to move continually outward over the disk surface until it is forced into the pickup groove. Here, the particle-laden liquid is picked up by a plastic probe and delivered to a point outside the unit for analysis.

The plastic nozzle has a 3 inch diameter inlet which converges to a 1-1/2 inch diameter; it serves to insulate the high voltage plate from the rest of the unit. The high voltage lead plugs into a receptacle in the nozzle; the receptacle is fastened to the high voltage plate.

The 7 inch diameter, high voltage aluminum plate has an insulating back to prevent arcing to the top cover. The stainless steel needles, from which the corona discharge emanates, are fitted into the plate through exact-size holes to insure good electrical contact and to keep them in the correct position. They protrude 1/8 inch from the bottom surface of the high voltage plate and are set back 1/2 inch from the edge of the orifice.

The 10 inch diameter aluminum collection disk has a groove at its outer rim into which the collection liquid is centrifugally forced and where it is picked up by the liquid pickup probe. The disk is mounted on the shaft of a 1/50 hp, 1725 rpm ac motor.

The plastic pickup probe is mounted near the right front corner of the sampler. The probe is made of Kel F, a plastic manufactured by 3M Company, St. Paul, Minnesota. The mounting mechanism is adjustable, allowing exact positioning of the probe. Alignment and position of the probe is somewhat critical; it must fit closely in the groove of the rotating disk in order to properly pick up the liquid. Excessive tension on the probe will overload the disk motor.

The air mover is a 3 inch vaneaxial blower powered by a 115 volt universal motor. The speed of the blower can be adjusted by the variac to provide the desired air flow. A Magnehelic gauge indicates the pressure differential across the sampler. The operating point, 1000 l/min, is indicated on the face of the gauge. The pressure drop for this flow rate is 0.52 inches water.

The high voltage for corona and collection processes is provided by a 0 - 20,000 volt dc power supply. The voltage is variable within this range, with a maximum output of 5 milliamps. A fuse in the high voltage line will prevent damage to the power supply if it becomes overloaded.

The top cover assembly contains a liquid reservoir which holds 1300 ml, or enough for about 18 hours operating time at a liquid flow rate of 1 ml/min. The cover contains the liquid input and flow control device which allows regulation and maintenance of a uniform flow rate. The plastic nozzle and high voltage plate are fastened to the cover by the nozzle retaining ring.

Tests on the various components of the prototype sampler were made after assembly. The blower moved about 1300 l/min through the sampler which is more than adequate. The original 1/70 hp disk motor was somewhat underpowered and it was replaced with a 1/50 hp unit. The high voltage power supply draws about 30 watts and is rated at 75 watts at 15,000 volts. The liquid pickup probe performs satisfactorily, although it is somewhat difficult to position.

2. Fractionator

The modified processing cup for the Fractionator is similar to the cup for the present Fractionator, except for reduction in diameter and height. With a reduction in diameter, there will be a corresponding reduction in g-force for an equivalent rpm; however, this has been compensated for by designing the cup so that the film thickness is proportionately less than that of the larger cup. At some operating speed both cups should have equivalent separation capabilities. The dimensions of the 1 ml/min cup were so chosen that this speed would be 10,000 rpm. At other operating speeds the separation capabilities would not be exactly the same for the two cups.

Tests made with artificial mixtures of glycerin and Arizona road dust (ARD) (particle density - 2.7 g/cm^3) indicated that the separation efficiency of the modified cup was equivalent to the original cup. However, in tests with polystyrene beads (particle density - 1.05 g/cm^3), the separation efficiency was not equivalent. A modification was made to the cup by increasing the inside diameter of the upper 1/4 inch of the

cup by 0.026 inches. This doubles the film thickness from the previous 0.013 inches, giving more time for particles to be separated. At the same time this increases the volume of the cup and thus the process time by about 10%. With this modification the separation capability of the cup for polystyrene beads was equivalent to the present cup.

The liquid thrown off the 10 ml/min rotating processing cup had been collected by a concentric cylinder and allowed to drain out at the bottom of the cylinder. This method for a liquid flow rate of 1 ml/min increased the response time of the processing unit much more than desirable. To reduce the response time to an acceptable level a modified collector cup was designed and built. This modified cup consists of a slowly rotating concentric cylinder and wiper. The collector cup and the processing cup form a pair of rotating concentric cylinders with the collector cup being the outside cylinder. As the liquid is thrown off the processing cup it is collected on the inside wall of the collector cup and removed by the wiper. For the modified cup, the response time of the Fractionator is on the order of one minute, and a negligible amount of liquid mixing occurs.

The prototype model of the Fractionator is shown in Figures 8 through 11. A list of basic nominal statistics follows:

Size = 12-1/4" x 11-3/4" x 15-1/4" high
Weight = 58 lbs
Processing cup = 1-1/2" inside diameter
Processing cup = 1" inside height
Processing cup operating volume = 1.1 ml
Collector cylinder = 3" inside diameter
Power input (max.) = 100 watts (at 115v, 60 cycle)

The cover is hinged and can be opened by loosening the quarter-turn screws. The lower portion of the front plate can be opened in a similar manner. The upper portion of the front panel contains the control panel, power input receptacle, liquid output opening and calibration chart.

The processing cup drive motor is a 1/4 hp, 1750 rpm dc shunt wound motor. Power to the motor is supplied by a full wave SCR circuit and speed is controlled by varying the armature voltage. This type of motor was used because of its inherent speed stability and wide speed range.

The high speeds required of the centrifuge were achieved by using a two-stage speed step-up of belts and pulleys which gives a speed ratio of about 20:1. The final speed step-up is a modified commercial unit (International Equipment Company #100, Multispeed Attachment for size 1, Model SBV Centrifuge).

The processing cup has an operating volume of about 1.1 ml; therefore, the process time for a 1 ml/min flow rate is 1.1 minutes. During preliminary testing the cup was found to operate satisfactorily at low speeds but at speeds over 10,000 rpm there was a severe vibration problem. This vibration was caused by a low frequency circumferential motion of the liquid. To eliminate this, four vertical, equally spaced bars were placed around the inside of the processing cup. There are, however, harmonics which cause some vibration at certain speeds.

The liquid collector cup is driven at about 10 rpm by an O-ring belt and pulleys. The drive motor is a fractional hp, 20 rpm ac synchronous motor. Liquid is removed from the collector cylinder by a spring-loaded plastic wiper, from which it drains by gravity through rubber tubing to the outside of the Fractionator for analysis.

The Fractionator was tested for separation efficiency and the results were similar to those for the laboratory model. After some modification of the wiper the processing time of the unit was on the order of one minute. At the higher speeds of the processing cup a small percentage of the liquid droplets thrown off the edge of the cup are deposited on the plexiglass collector cover. However, the amount of liquid lost in this manner is negligible and does not interfere with operation of the unit.

C. Interpretation

The sampler was thoroughly tested and has performance characteristics comparable to the present Large Volume Air Sampler. It is capable of collecting, on a per minute basis, the particulate matter from 1000 liters of air and concentrating it into one milliliter of glycerin, a concentration factor of 10^6. Its efficiency of collection is in the range of 80% for 0.2 micron particles and approaches 100% for 3 micron particles. Processing time, the time from the moment an air-borne particle enters the collector until the moment it is discharged from the sampler (suspended in glycerin), is on the order of one minute.

The Fractionator has performance comparable to the present liquid processing unit. For example, using 90% glycerin at a flow rate of 1 ml/min with the processing cup at 10,000 rpm, 95% of the particles with a density of 2.7 (with the size distribution of ARD, Figure 14) will be removed. Approximately 83% of the particles with a density of 1.05 (with the size distribution of polystyrene beads, Figure 14) will be removed. At the same time about 17% of the biological material of the size and density of Bg will be removed. The processing time of the Fractionator is on the order of one minute.

The sampler and fractionator in combined operation will deliver a concentrated, clarified atmospheric sample to a continuous flow system. The two units are independent and can be operated as such. For example, the Fractionator can be used to remove particulate matter based on density differential from any particle laden liquid.

D. Decisions

After final assembly and testing both the sampler and fractionator were shipped, to arrive at Melpar, Inc. on June 30, 1965.

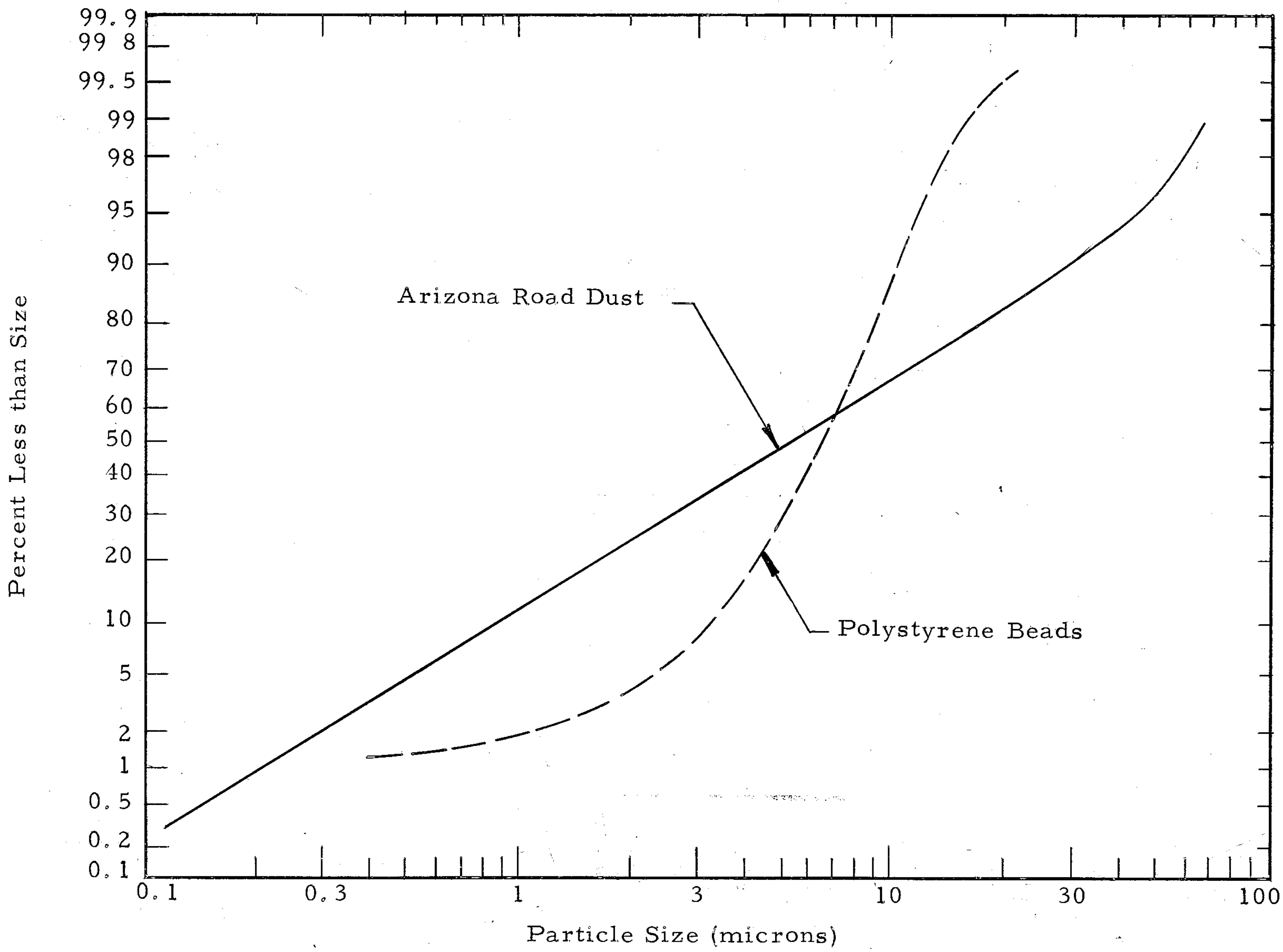


Figure 14. Particle Size Distribution of Arizona Road Dust and Polystyrene Beads

Although the sampler operates satisfactorily, suggestions for possible changes to improve its reliability and performance are presented. Some aspects of liquid pickup could be improved by using a system similar to that used in the Fractionator, i. e., a concentric rotating ring or cylinder to catch the liquid thrown off the rotating collector disk, with a wiper to collect the liquid. Although this modification would somewhat increase the weight and cost, it should reduce liquid mixing and require no critical alignment or positioning.

An incorporated liquid reservoir is desirable from the standpoint of compactness for the sampler. However, there are some drawbacks to this reservoir (cleaning, flow rate adjustment, a fixed volume) and an independent reservoir may be more desirable.

IV. EXPERIMENTAL DATA

A. Sampler - Laboratory Model

1. Disk Wetting

Tests on wetting of a rotating disk were made by using an anodized aluminum disk having a 12 inch diameter and rotating at speeds of 1000 - 1800 rpm. These tests are summarized in Table I.

Table I. Results of Disk Wetting Tests

Liquid	Liquid Flow Rate	Comments
90% glycerin + 0.4% Tween 20	1 ml/min	Wets the disk but flow is uneven, rivulets
90% glycerin + 0.1% Brij 35	0.1 ml/min	Does not wet disk, liquid runs out in 2 or 3 streaks
90% glycerin + 0.1% Brij 35	0.3 ml/min	Wets disk about 25%
90% glycerin + 0.1% Brij 35	0.6 ml/min	Wets disk about 50%
90% glycerin + 0.1% Brij 35	1 ml/min	Wets entire disk

2. Air Flow

Whenever a change in high voltage plate diameter or plate to plate spacing was made, the air flow versus pressure drop curve was determined for the laboratory model of the sampler. The air flow was measured by a propeller-type flowmeter, Model PR-2, designed by the Electronics Division of General Mills, Inc., now the Applied Science Division of Litton Systems, Inc. Figure 15 shows a typical calibration curve.

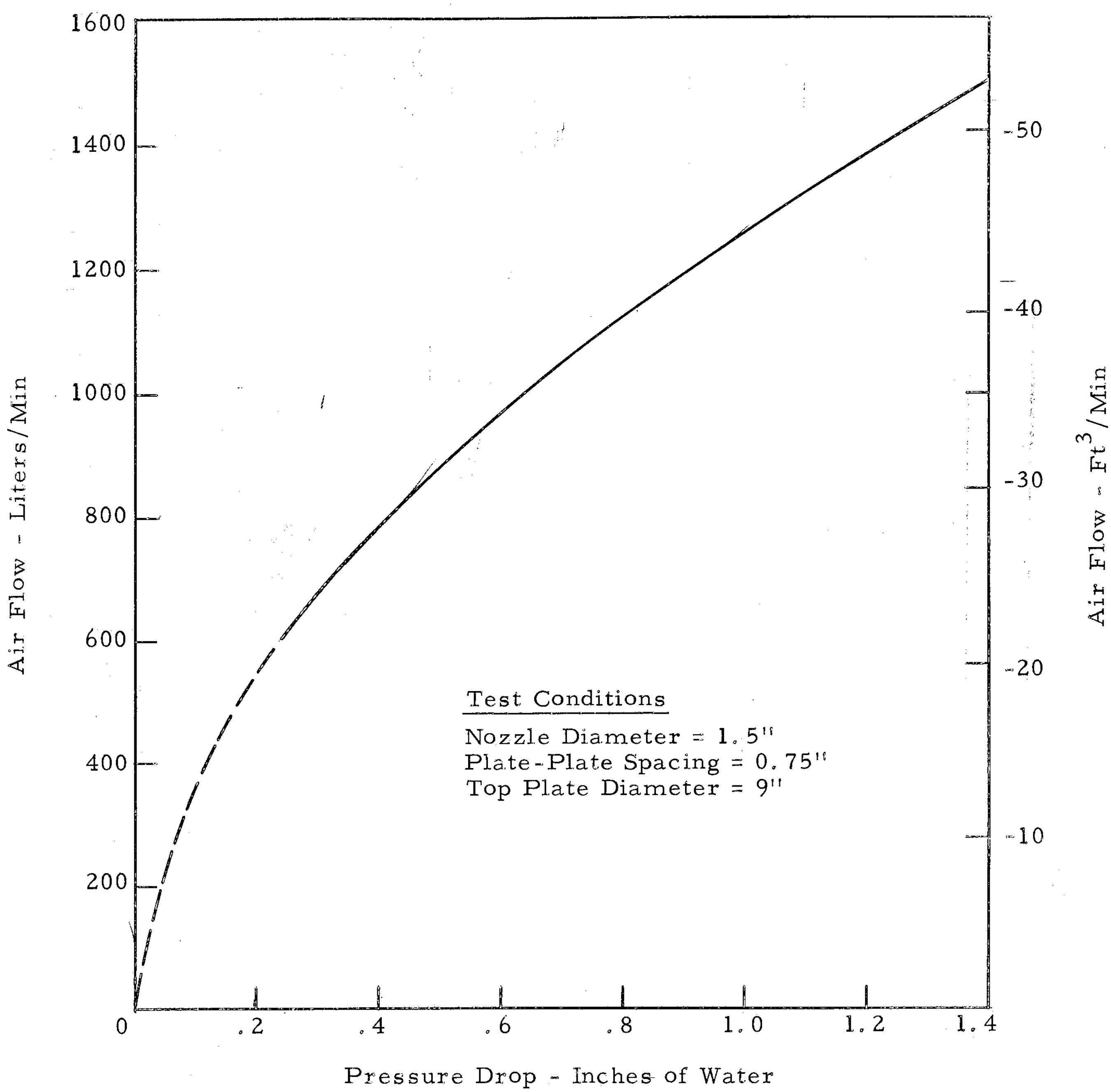


Figure 15. Typical Calibration of Airflow Versus Pressure Drop of Laboratory Model Sampler

3. Collection Efficiency

Diameter of the high voltage plate and the collector plate influences the collection efficiency since these dimensions determine the length of time a particle is subjected to the electric field. A series of tests were made varying the high voltage plate dimensions. Figure 16 shows the results of these tests.

Various tests were conducted to determine the effect of the voltage gradient on the collection efficiency. From electric field theory, the force on a changed particle is directly proportional to the magnitude of the electric field. Therefore, the higher the field strength, the greater the collection efficiency; also, particles of decreasing size can be collected. Figure 17 shows the results of one series of tests.

In general, a voltage gradient of 34-35 kilovolts per inch could be maintained just before arcing. However, above 26-27 kilovolts per inch, the collection efficiency change was insignificant for this unit. Therefore, with a plate to plate spacing of 9/16 inch, 15,000 volts on the plate gave near maximum collection efficiency and provided a satisfactory margin of about 20 percent under the voltage at which arcing normally occurs.

4. Liquid Pickup

Various types of liquid pickup probes were tested to determine the most effective size, shape and configuration. Table II shows the results of these tests.

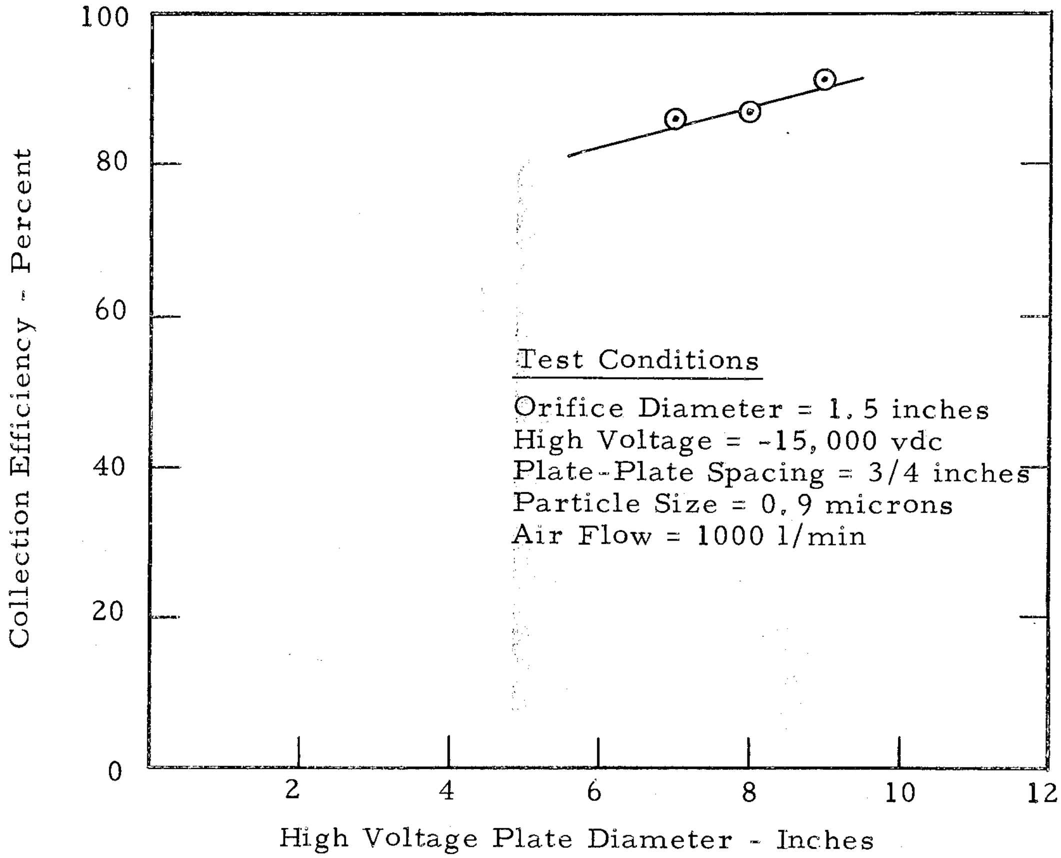


Figure 16. Relationship between Collection Efficiency and High Voltage Plate Diameter

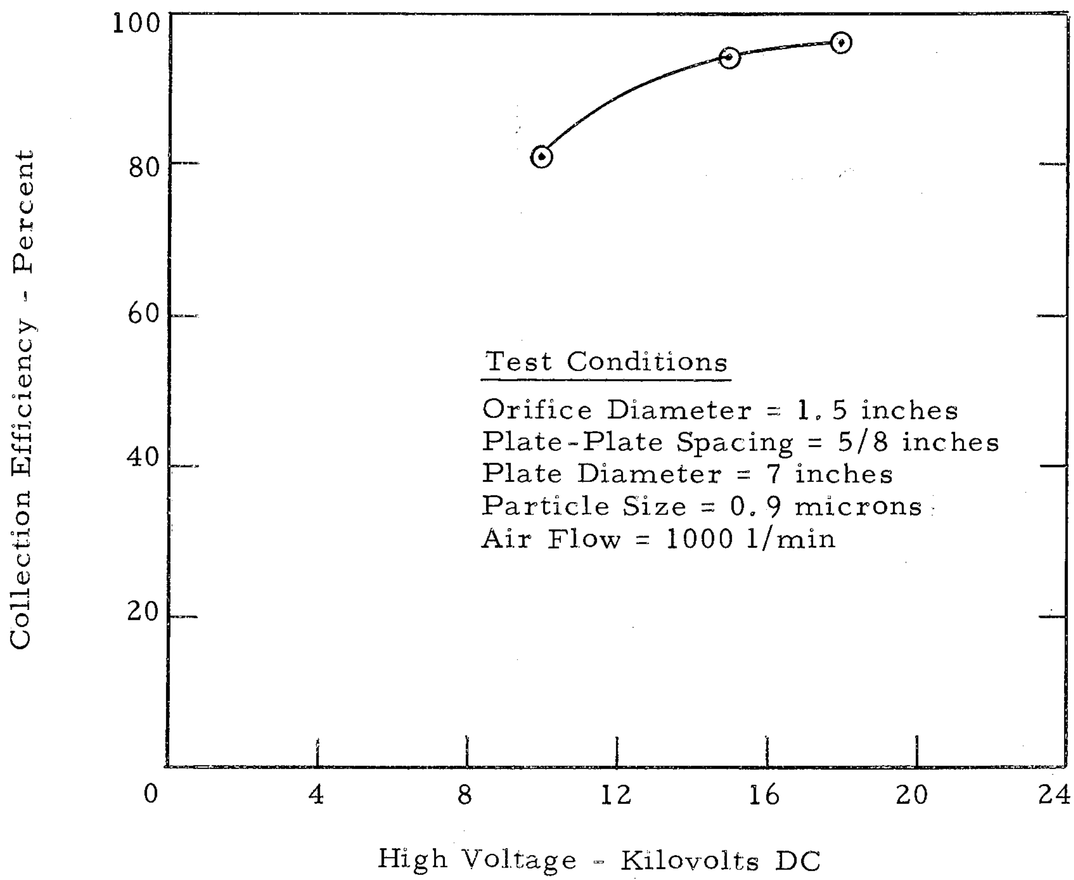


Figure 17. Relationship between Collection Efficiency and High Voltage on Top Plate

Table II. Liquid Pickup Probes

Probe Description	Comments
#1 - #18 Hypodermic Needle	Picks up only 0.6 cc/min, splash from downstream end of probe.
#2 - #16 Hypodermic Needle	Picks up only 0.7 cc/min, liquid forms drops at downstream end of probe.
#3 - .093" ID x .010" wall stainless steel tube	Picks up 1 cc/min but liquid sprays towards center of disk.
#4 - .125" OD x .032" wall copper tubing	Picks up 1 cc/min, no spray, but great deal of mixing.
#5 - .125" OD x .32" wall copper tubing with solder shield	Picks up 1 cc/min, no spray, very little mixing.

Probe #5 was a piece of tubing imbedded in solder. The probe was made by positioning the tubing in the groove of the disk (Figure 2), melting solder to fill up the groove around the tube, removing it after the solder had hardened and further shaping it. This liquid pickup (Figure 3) worked quite well, with very little mixing and response time of about one minute. Figure 18 shows the response time of this probe. The data for such a curve is obtained by placing a drop of glycerin containing uranine dye at the center of the rotating disk. The glycerin output of the pickup probe is sampled at measured time intervals (time = 0 at moment the drop of dye is placed). The glycerin is then analyzed fluorometrically for dye content.

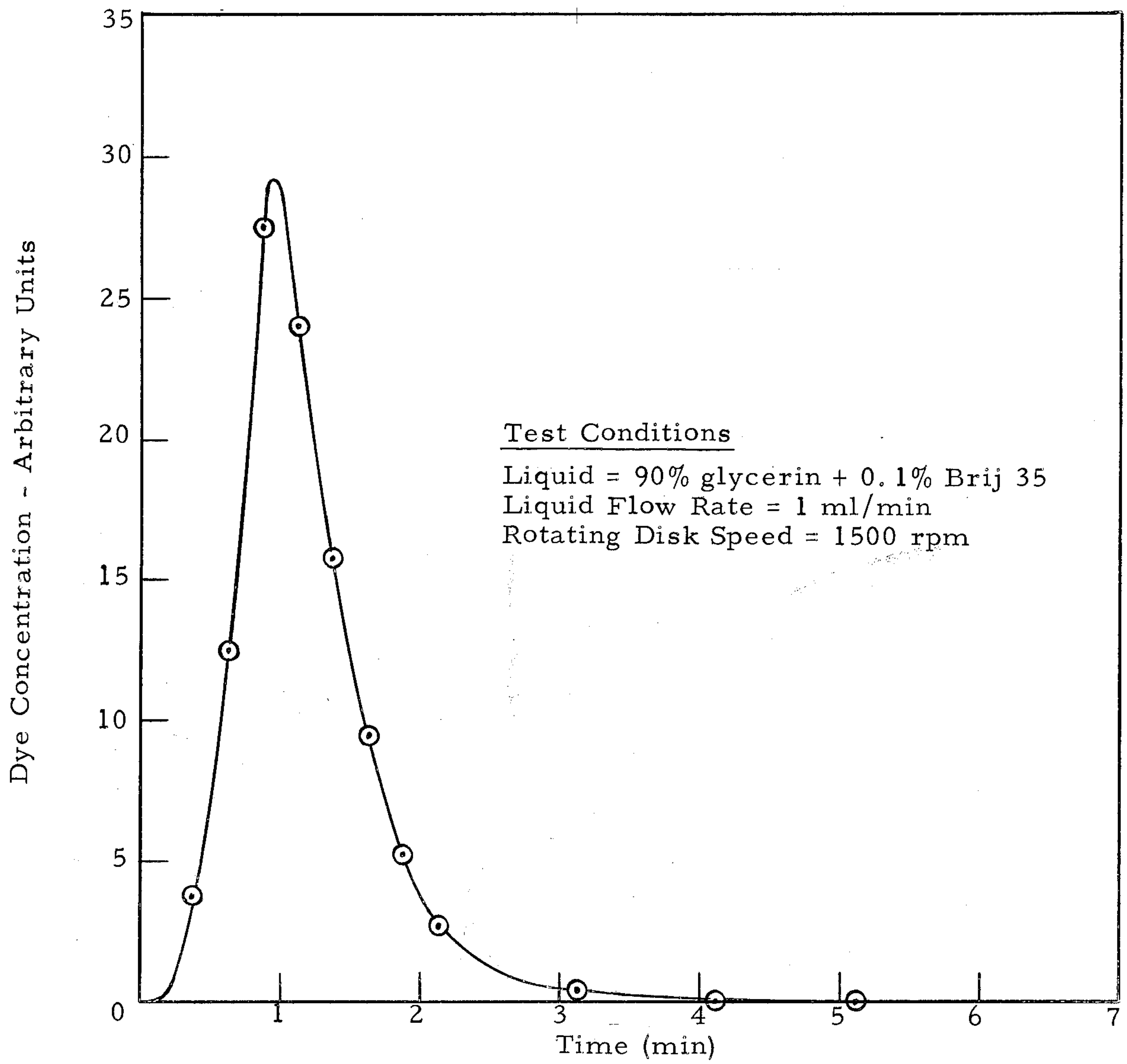


Figure 18. Process Time of Liquid Pickup Probe #5

5. Uniform Flow Device for Liquid Input

A uniform flow liquid reservoir was fabricated (see Figure 13) to determine if liquid flow would remain constant for varying liquid levels in the reservoir. Table III shows the results of these tests.

Table III. Tests on a Uniform Flow Reservoir

Test Conditions: Liquid = 90% glycerin + 0.1% Brij 35
Flow Restricting Orifice = 0.028" Dia.
h_2 = 3"

h_1 (Liquid head, inches)	Liquid Flow Rate (ml/min)	
	Open Reservoir	Uniform Flow Reservoir
0	1.04	1.02
1	1.80	1.12
2	2.27	1.04
3	2.63	1.00
2		1.26
1		1.25
0		1.08

Although this device gives a uniform flow rate, it should be noted that temperature does have a minor effect on the flow rate. For high accuracy, calibration should be performed for a specific temperature range.

B. Sampler - Prototype Model

1. Air Flow

An air flow versus pressure drop calibration curve is shown in Figure 19. By varying the voltage to the blower, air flow rates up to 1300 liters/min can be obtained through the sampler. At the

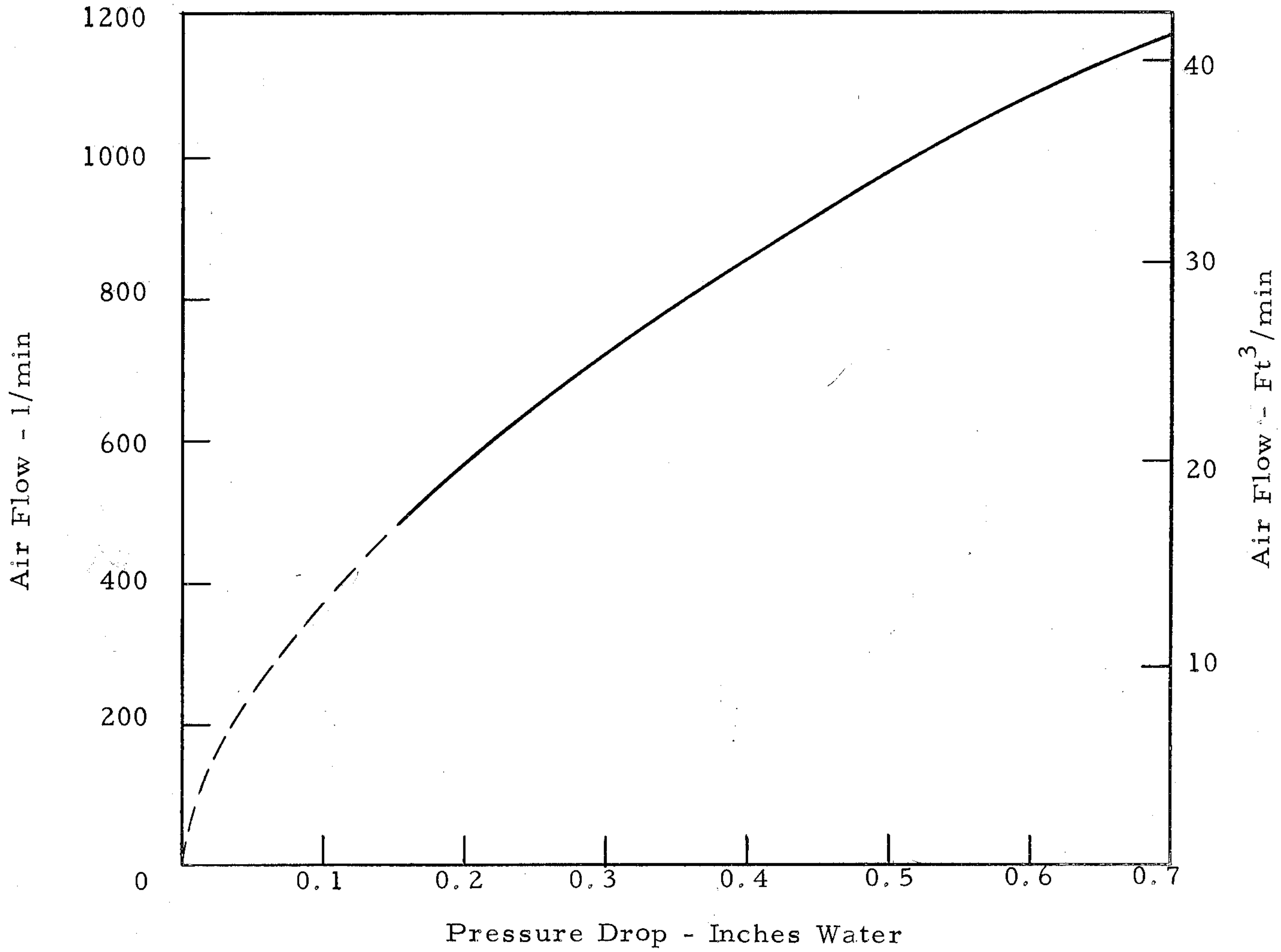


Figure 19. Flow vs. Pressure Drop of Large Volume Air Sampler - Model M

designed air flow rate of 1000 liters/min the pressure drop through the sampler is 0.52 inches water.

When the inlet to the sampler is unobstructed the calibration curve is correct. If ductwork or other attachments are on the inlet to the sampler, the Magnehelic gage will not read the correct air flow rate. The high pressure side of the gage must be connected to a static pressure tap at the inlet to the sampler. An alternative would be to recalibrate the sampler air flow versus pressure drop with the ductwork attached.

2. Collection Efficiency

Figure 20 shows the collection efficiency of the sampler for a range of particle sizes. Efficiency tests were made by generating aerosols using uranine dye solutions of various concentrations. Sampling the inlet and effluent air to determine the relative dye particulate concentration is a fast and accurate method of determining the collection efficiency. Tests were made using *Bg* to determine the collection efficiency of the sampler for biological particulates. A solution containing about 3×10^4 *Bg* spores per ml of distilled water was atomized with a Vapronefrin nebulizer operating at 7.5 psig. The sampler inlet and effluent air was sampled by Anderson samplers to determine the relative *Bg* concentration. The collection efficiency for an average of six tests was 93%.

3. Response or Process Time

Figure 21 shows the response time of the prototype sampler. It is on the order of one minute.

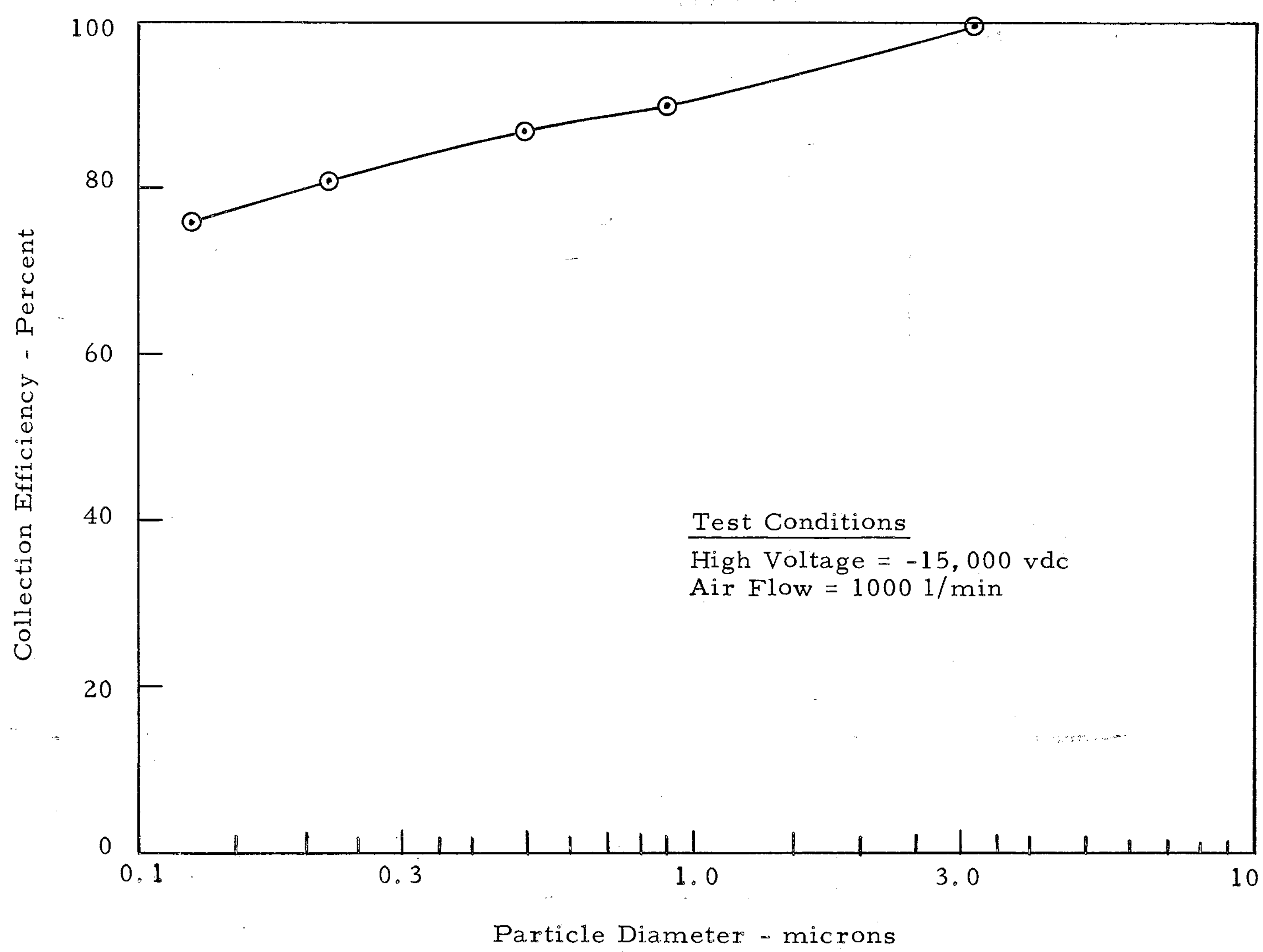


Figure 20. Particle Diameter vs. Collection Efficiency of Large Volume Air Sampler - Model M

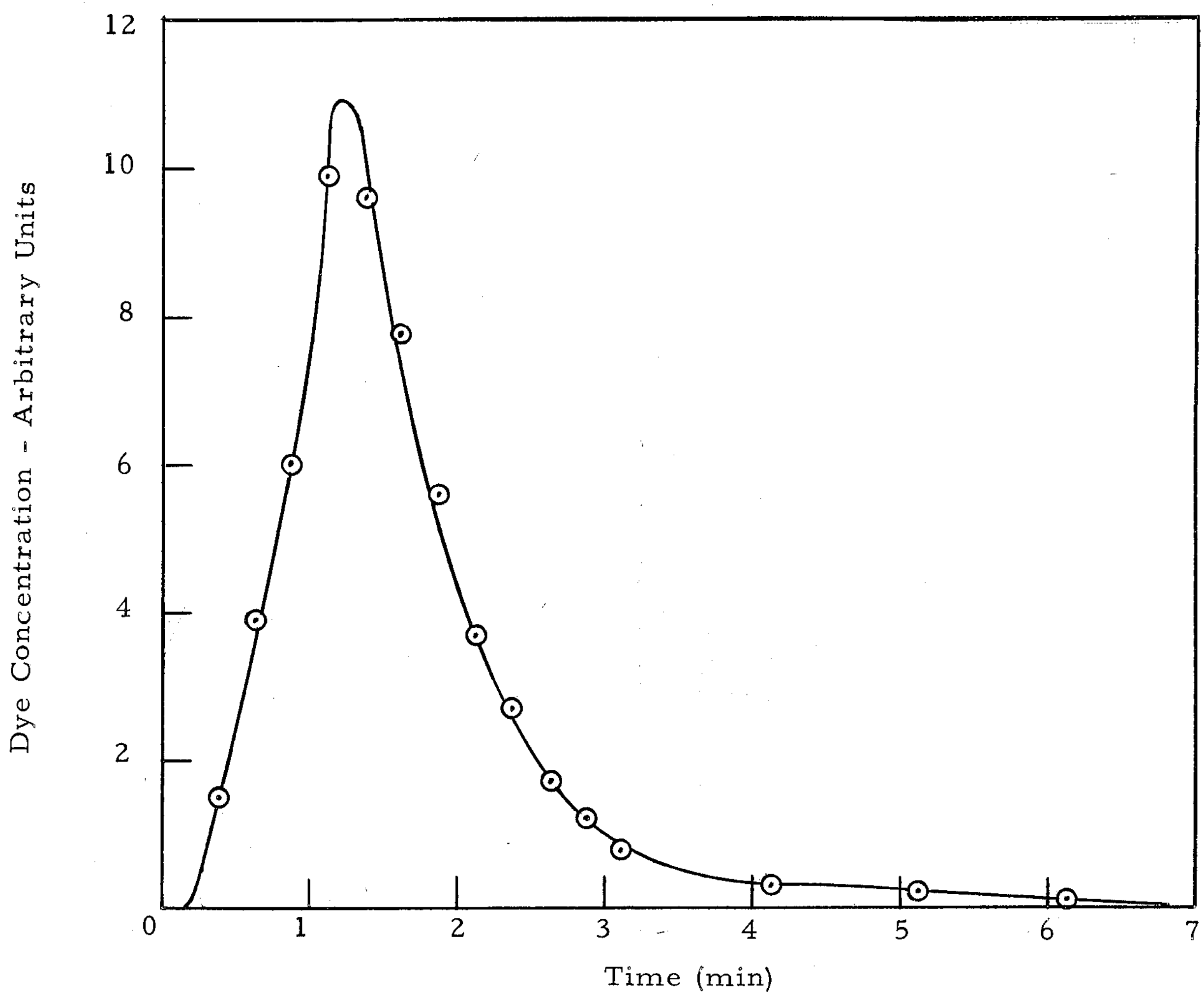


Figure 21. Process Time of the Large Volume Air Sampler - Model M

C. Fractionator - Prototype Model

(Tests on the laboratory model and the prototype model of the Fractionator were essentially identical. Therefore, only data for the prototype model is presented.)

1. Separation Efficiency

Tests to determine the separation capabilities of the Fractionator were made by using the following suspensions:

1) 0.3% Arizona road dust (ARD) in 90% glycerin

2) 0.1% polystyrene beads in 90% glycerin

3) Bacillus Globigii (Bg), count ~300/ml, in 90% glycerin

Figure 14 shows the particle size distribution of Arizona road dust and polystyrene beads. The Arizona road dust and polystyrene bead mixtures were made by adding the particulate matter to the liquid and stirring the mixture while subjecting it to ultrasonic vibration. The particulate concentration of the suspensions was measured by using the MSA-Whitby particle size analyzer apparatus. Comparison of the concentrations before and after processing by the Fractionator gives the percentage of particulate matter removed. Concentrations of Bg were measured by plating out small aliquots of the solution before and after processing and counting the spore colonies.

The results of the separation efficiency tests are shown in Figure 22. Interpretation of these results should be made by referring to the size distribution curves of Figure 14. The curves of Figure 22 would not be the same for particulate matter of any other density or size distribution.

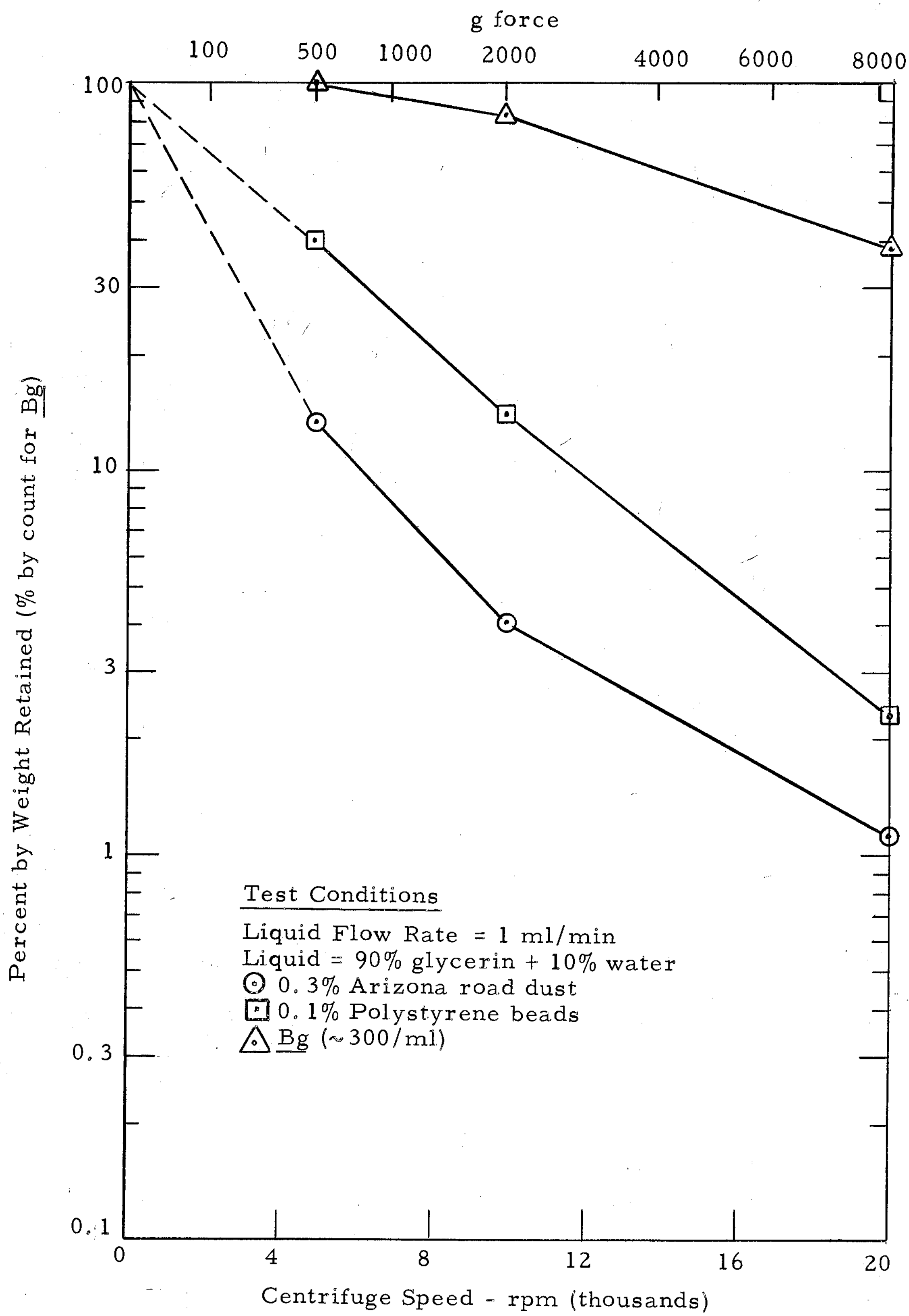


Figure 22. Relationship Between Fractionator Cup Speed and Particulate Matter Retention

The curve for Bg is the result of only one set of tests. Since experimental biological accuracy is relatively poor, the results should be interpretated accordingly. An average of the results of five to ten series of tests would give more reliable results.

2. Response or Process Time

The process time for the Fractionator is shown graphically in Figure 23. For this test a drop of glycerin containing uranine dye was injected at the inlet to the Fractionator at time = 0. (Fractionator cup speed = 10,000 rpm, liquid was 90% glycerin at 1 ml/min flow rate.) The liquid output of the Fractionator was collected in aluminum foil dishes at measured time intervals and analyzed for dye content in a fluorometer. As Figure 23 shows, dye started to come out after 35 seconds, reached a peak at 70 seconds, and after 120 seconds, 90% had gone through. The spread in the dye output is due to mixing of the liquid which occurs in the cup, on the inside of the collector cylinder, and through the tubing.

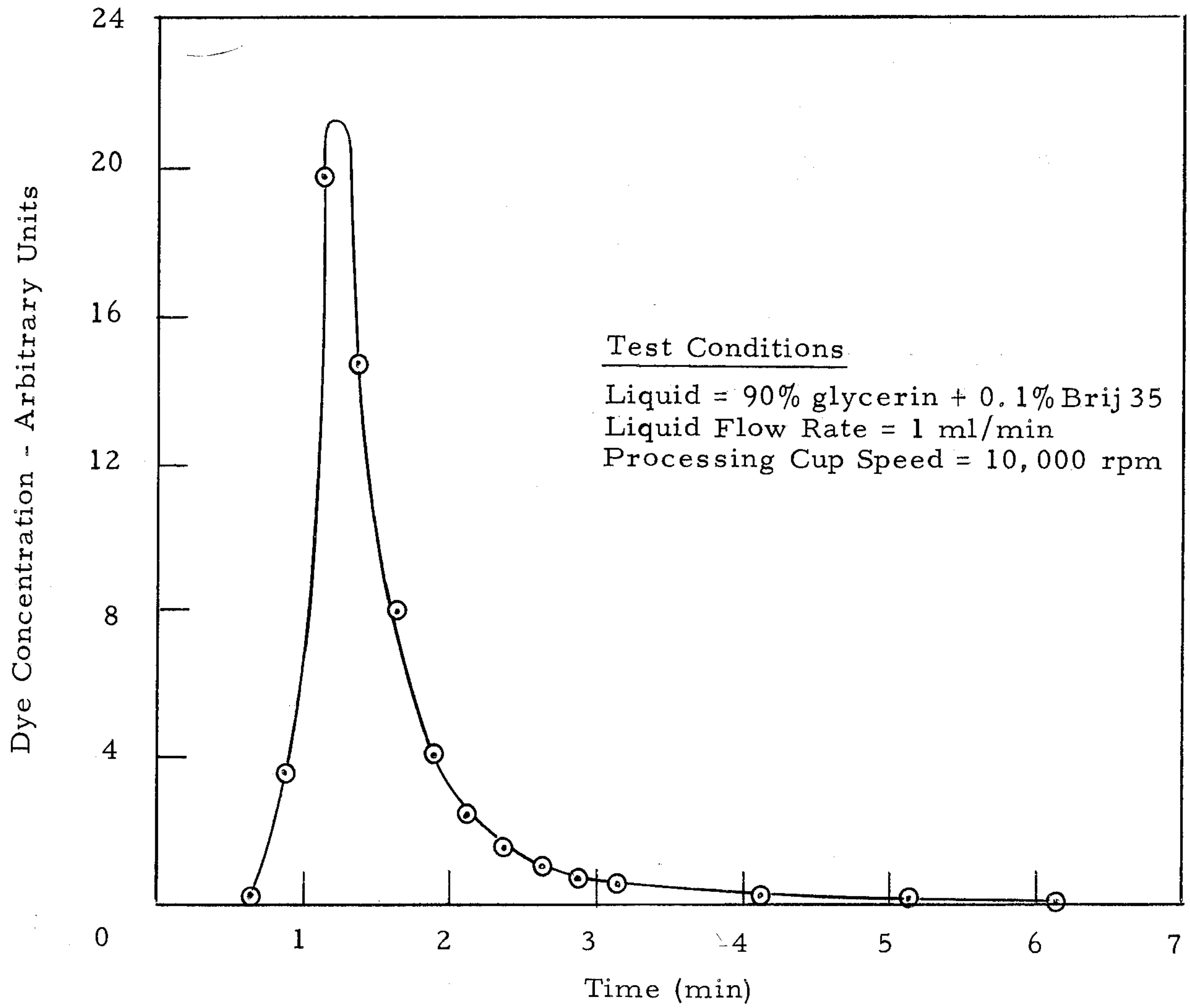


Figure 23. Process Time of Fractionator

V. REFERENCES (General)

"Development of an Aerosol Collector for use in a Microbiological Aerosol Detection System," Applied Science Division, Litton Systems, Inc., Report No. 2548, 30 October 1964. (Contract No. DA-18-064-CML-2849(A)).

"Continuous flow Fractionator for the Large Volume Air Sampler," Applied Science Division, Litton Systems, Inc., Report No. 2659, 16 November 1964 (Contract No. DA-18-064-CML-2849(A)).

VI. ABSTRACT

The results described in this report conclude a seven month effort to fabricate, design, test, and deliver a miniaturized version of the Large Volume Air Sampler and a compatible fractionating unit. The sampler is capable, on a per minute basis, of efficiently and continually collecting the particulate matter from 1000 liters of air and concentrating it into 1 ml of liquid. The Fractionator receives the liquid output from the sampler and removes most of the non-microbiological particulate matter while retaining a major fraction of the biological particulates. The sampler and fractionator are integral units and can be operated conjunctively or independently.

no under-line

Studies were made to determine the optimum configuration for maximum collection efficiency consistent with reasonable size, weight and power requirements. Aerosols containing particles of known size were generated to test the collection efficiency of the sampler for particles over a wide size range. Various types of probes were tested to determine the best configuration for picking up the liquid without the aid of a pump from the edge of the rotating collector disk and delivering it outside the sampler for analysis. The process time of the sampler, the time period between which an air-borne particle enters the sampler and when it is delivered in the liquid outside the sampler, is on the order of one minute.

The fractionator processing cup was designed to process liquid at the flow rate of 1 ml/min. Tests were conducted to determine its separation capabilities for particles more dense than and less dense than the liquid (glycerin). Retention of biological matter was determined by testing with Bg. The method of liquid removal after processing was investigated; the final configuration is such that the process time for the fractionator is on the order of one minute.

cont

The prototype units are designed for continuous, routine operation to deliver a concentrated atmospheric sample to continuous flow systems. The overall combined response time of the two units is on the order of two minutes.

end